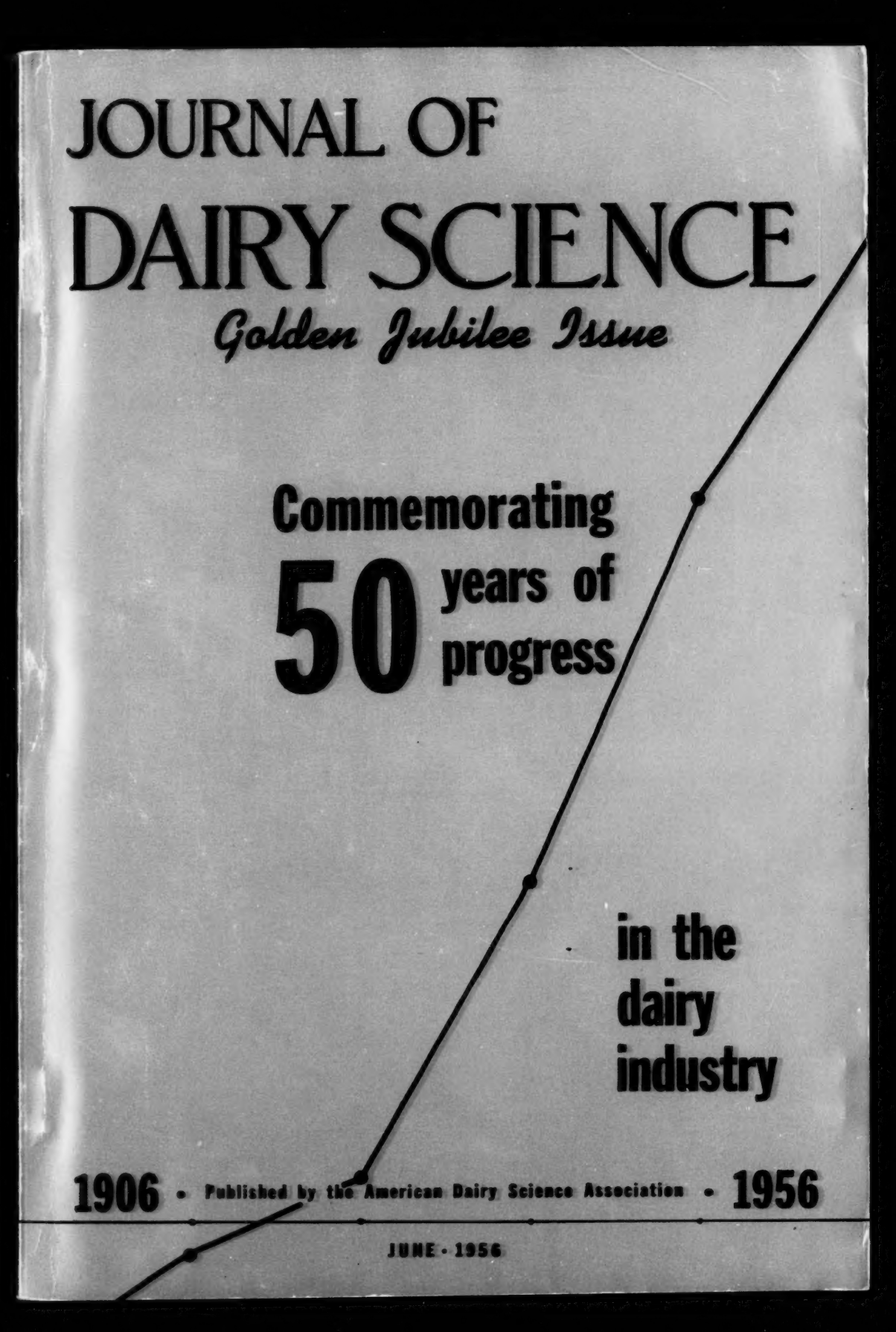
JOURNAL OF DAIRY SCIENCE

Golden Jubilee Issue



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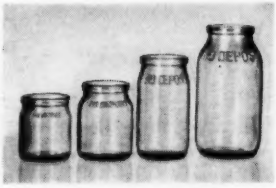

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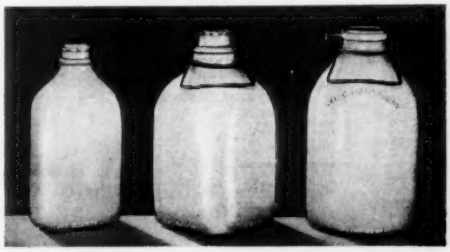

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it
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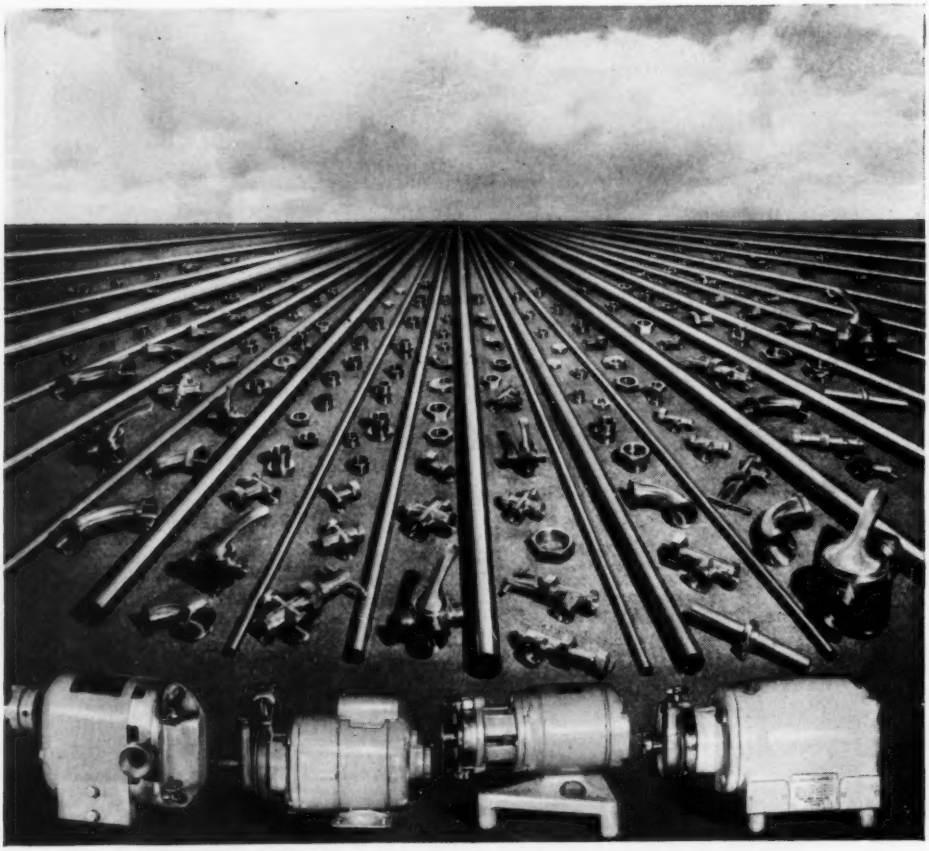

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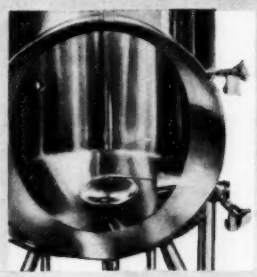

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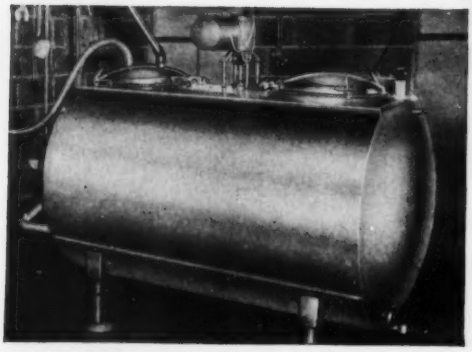

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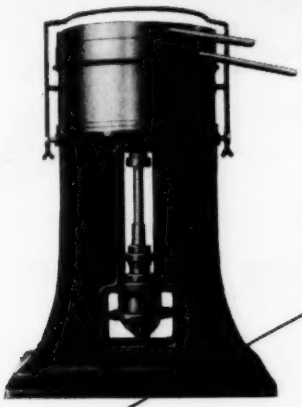

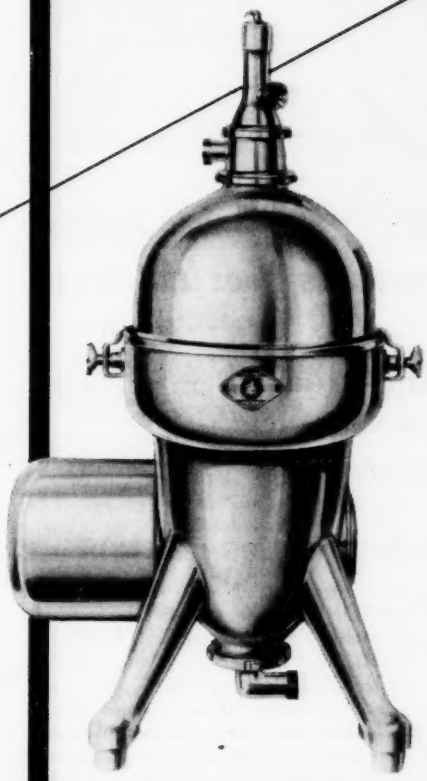

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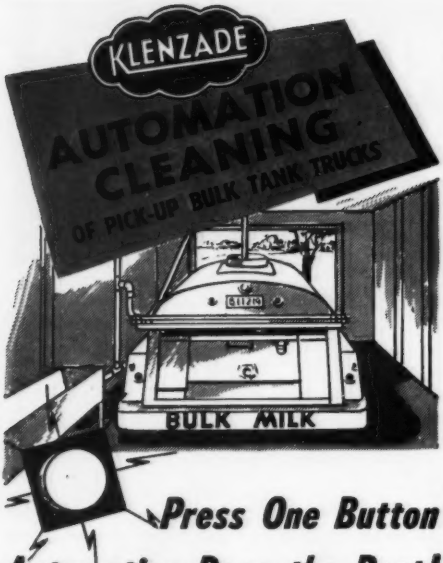

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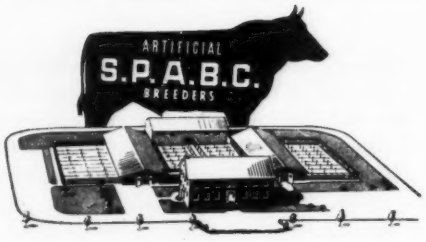
These ideas are still the main objectives of the industry—an industry, by the way, which we believe deserves tribute for its basic idealism, and of which we are proud to be a part. But, as the record of the industry is being written, it is becoming more and more clear that many sires have turned out poorly, that some have spread disease, and that the industry as a whole has not produced the gains for which we hoped, and toward which so many persons have contributed so much. This is a very forcible reminder that we cannot expect progress from the mere technique of artificial breeding alone.

To discharge the heavy burden of responsibility we bear for the breeding of over 900,000 cows annually, American Breeders Service, a pioneer in the industry, spares no pains in the planning or execution of our sire selection and health programs. We contribute substantial sums annually to research—through the American Foundation for the Study of Genetics, Madison, Wisconsin, and other institutions of learning, private research establishments, and our own Research and Development Department. We salute American Dairy Science Association on this, its Golden Jubilee, for the contributions to the field made by its members. We look forward to continuing to work with them toward the accomplishment of our common goals.

AMERICAN BREEDERS SERVICE
325 North Wells Street
Chicago 10, Illinois

Greater than You Think



It is very timely that the dairy industry are making great strides in "Herd Improvement" in this day and age when all industries of our great land are working so vigorously toward more efficient production.

Cooperative Artificial Breeding is the key-note to these rapid gains in "Herd Improvement."

Concurrent to dairymen all over the nation, dairymen in Southeastern Pennsylvania have organized and developed a scientific breeding program for themselves that is safe, sound and very economical.

TIME HAS TOLD

That top production combined with desirable type can be attained by following a breeding program concentrated on "Proven Sires" and that economy and security can be attained and maintained in a breeding program owned and operated by those who use and depend on its services.

ALWAYS A CHOICE OF SIRES WITH S.P.A.B.C.

Southeastern Penna.
Artificial Breeding Cooperative

Box 254 Lancaster, Pa. Phone 2-2191

Serving Southeastern Pennsylvania and Delaware

Congratulations

American Dairy Science Association

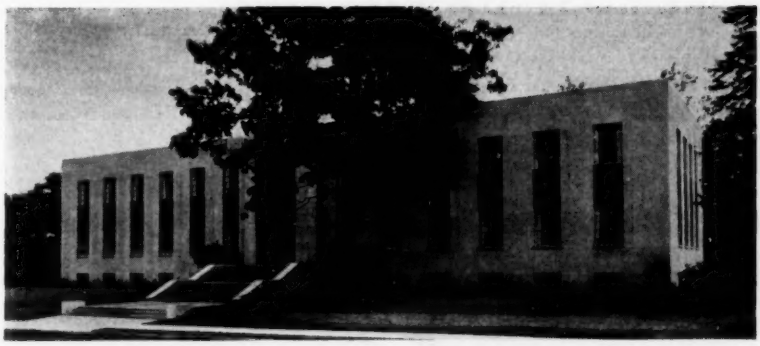
on your 50th anniversary

We salute the American Dairy Science Association on its 50th anniversary. The dairy research of its various members, and the application they have made of it during the past half century, has enabled our country's dairy industry to lead the world in accomplishment.

The American Jersey Cattle Club is vitally interested in dairy research. Through the years it has sponsored various research studies in cooperation with the land grant colleges. The findings of these studies have greatly aided the improvement programs of the Jersey breed.

Now the results of new research on milk are being applied to the All-Jersey Milk program. This rapidly expanding program depicts another forward step in milk merchandising.

Thanks, American Dairy Science Association, for your good work. The Jersey breeders of America look to you for continued research and guidance in the 50 years ahead.



Headquarters office of The American Jersey Cattle Club in Columbus, Ohio. It is the oldest dairy breed registry organization in America.

THE AMERICAN JERSEY CATTLE CLUB

1521 EAST BROAD STREET, COLUMBUS 5, OHIO

congratulations

and best wishes for your

next 50 years to the

AMERICAN DAIRY SCIENCE

ASSOCIATION *from*

FOREMOST DAIRIES, INC.

operators of the longest

milk route in the world

THE AMERICAN DAIRY ASSOCIATION

what it is... where it is going

In 1940 representatives of six midwestern and northwestern states organized the American Dairy Association. Their purpose was to create an organization through which dairy farmers could finance a program of advertising, merchandising, public relations, and research which would result in the sale of more dairy products.

Today the American Dairy Association is in active operation in 45 states. Its growing budget permits the development of powerful promotion programs which have earned the respect and cooperation of the dairy industry, the food distribution industry, and the government.

The function of the American Dairy Association is to strengthen consumer knowledge of and demand for dairy products. It is not established to promote or influence legislation. Its target is the American homemaker.

The American Dairy Association is supported through the voluntary investment of dairy farmers. At the start of 1956, more than half the states in the program are on a voluntary year-round set-aside.

The American Dairy Association is governed by dairy farmers elected by and from its membership. Each member state has a state organization which chooses its own officers and elects delegates to the national governing body. Officers of the national organization serve without pay. Day to day business is carried on from executive headquarters in Chicago by a staff of full-time employees.

Does the program work? Non-farm consumption, per capita, of fluid milk and cream increased four quarts from 1954 to 1955. In 1955, as in 1954, per capita consumption of butter and ice cream has increased. Government purchase of surplus dairy products in 1955 dropped almost 50% below the 1954 level in spite of a 1.4 million pound increase in farm milk production. Market studies made by the Association indicate that more families are buying butter.

The American Dairy Association program for 1956 is set up on a budget which is to be invested in advertising in television, radio, newspapers, and magazines plus research, merchandising and public relations.

One of the outstanding advertising forces is the Disneyland program which for 15 months has been consistently in the top 10 of all television programs. Throughout 1955 it reached an average of 40 million people weekly.

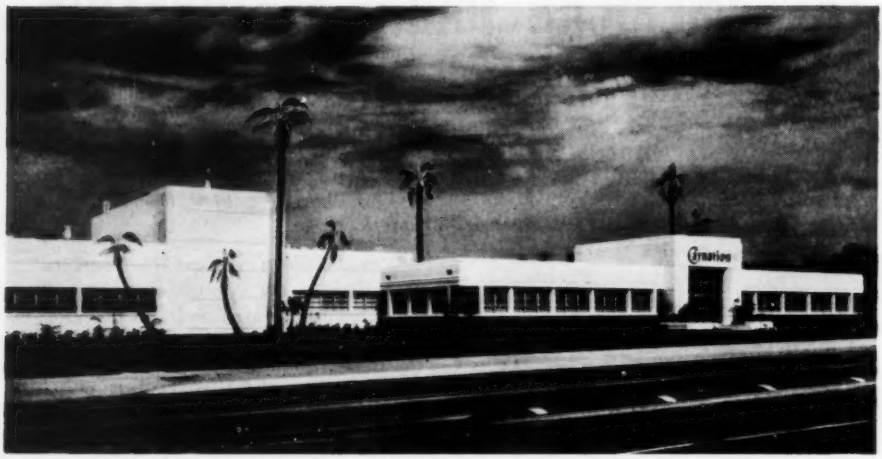
The American Dairy Association has grown because it has worked with the dairy farmers of America to make homemakers more conscious of the reasons why nourishing, refreshing and tasty dairy foods are important to better living.

Your road to sales

AMERICAN DAIRY ASSOCIATION

20 North Wacker Drive, Chicago 6, Ill.

Report | from Carnation Research Laboratory



Carnation Research Laboratory, 8015 Van Nuys Boulevard, Van Nuys, California

General Research

For a half century, Carnation has conducted a continuous and expanding 5-phase research program in dairy and cereal products. Newest major research facility is the Carnation General Research Laboratory at Van Nuys, California–one of America's most modern laboratories devoted exclusively to product research.

Qualified Scientific Staff

At the Van Nuys Laboratory alone, a large Carnation staff of graduate scientists represents an extremely broad background; fields covered include biology, bacteriology, parasitology, dairy technology, chemistry, biochemistry, organic chemistry, food technology, dairy husbandry, dairy bacteriology, dairy manufacturing and agricultural engineering.

Continuous, Planned Research

protects the high uniform quality of both established and new Carnation products.

Greetings to the American Dairy Science Association on their 50th Anniversary from

Carnation Company

Los Angeles, California

Our very best wishes to the American Dairy Science Association upon its

50th

Anniversary

•

Bowman

Dairy Company

140 W. Ontario St. Chicago, Ill.

WE, THE INDUSTRIALIZERS OF MILK,

Salute . . .

AMERICAN DAIRY SCIENCE ASSOCIATION

On its 50th anniversary

ADSA's 50 years of service to the Dairy Industries have been integral factors in making the 20th Century the Dairy Century.

Dairy Industries Supply Association
sponsors of
The 20th Dairy Industries Exposition
October 29–November 3
Atlantic City

1906 The Golden Years 1956

. . . in an industry as old as the history of mankind!

We pay tribute to the American Dairy Science Association for a half century of worthy achievement in the interests of producers, processors, and consumers of dairy products.

FAIRMONT

FAIRMONT FOODS COMPANY

General Office Omaha, Nebraska

Congratulations

to the

AMERICAN
DAIRY SCIENCE
ASSOCIATION

on its

50th Anniversary

•

Sealtest
TRADE MARK
DAIRY PRODUCTS

NEW ENGLAND'S ONE STEP AHEAD DAIRY

Hood

Quality Dairy Products Since 1846

Congratulations A.D.S.A.

Your achievements are the cornerstone of progress for the next 50 years.

Land O'Lakes Creameries, Inc.
MINNEAPOLIS 13, MINN.

MURPHY PRODUCTS CO.
BURLINGTON, WIS.

FEEDING CONCENTRATES THAT BALANCE GRAIN AND ROUGHAGE

Congratulations to the
AMERICAN DAIRY SCIENCE ASSOCIATION
on its 50th Anniversary

VITEX LABORATORIES
DIVISION OF THE NOPCO CHEMICAL COMPANY
HARRISON, NEW JERSEY

How things have changed since 1906!

• And the dairy industry has kept pace with changing times, through new and improved methods of producing and processing man's most nearly perfect food.

• Progress in our industry always has been based solidly on research and teaching, and it always will be. Members of the American Dairy Science Association can take pride in having contributed so much to a healthier and better-fed America.

• We have been privileged for the past twenty of your fifty years to have had a part through the Borden Awards in recognizing some of you whose research achievements have been particularly notable. Now, in this Golden Jubilee year, we salute all members of the American Dairy Science Association. Together you have helped to bring about a new and better dairy industry, and are showing the way to further progress in the years ahead.

Borden's

Fine Dairy Products since 1857

MEYER-BLANKE CO.

LABORATORY DIV.

St. Louis, Mo.

Equipment and Products Scientifically Developed for Cultured Milk Products Manufacture

- Spray Type Nu-Vats for Cottage Cheese
- Mechanical Agitators
- Nu-Processor for Buttermilk and Cultures
- Nu-Acidi Tester
- Misc. Equip. for Cheese and Buttermilk Mfg.
- BMF—Distilled Culture
- Angevines Cottage Cheese Coagulator
- Cultures—Liquid or Powder
- Mineral Ade—Soln. of Calcium and Magnesium
- Nu-CD (Fortifier)—For Cottage Cheese Dressing
- Nu-1.60—To Balance Mineral Salts and Acid
- Nu-Tone—Intensifier
- Nu-Granule Color—for Buttermilk Flakes
- Shallot Blend—For Chive Style Cottage Cheese
- Vegetable Mix—For Garden Salad Cottage Cheese
- Vitamins—Oil and Milk Carriers

Write for Additional Information

A Great Feed

HALES & HUNTER CO.

Manufacturers of

PIONEER DAIRY FEEDS

Both Working Together to Point the Way to a Better Tomorrow in Dairying

A Great Organization

THE AMERICAN DAIRY SCIENCE ASSOCIATION

Congratulations to the American Dairy Science Association on your 50th Anniversary. We have the utmost confidence in you . . . . and your continued success.

HALES & HUNTER CO.

141 West Jackson Boulevard Chicago 4, Illinois

Mills at:

Chicago, Illinois Marshall, Missouri Cartersville, Georgia

Wilmington, Delaware Lexington, Kentucky Springdale, Arkansas

PIONEER DAIRY FEEDS

CONGRATULATIONS
on your
GOLDEN ANNIVERSARY

OHIO SWISS CHEESE
ASSOCIATION, INC.
Sugar Creek, Ohio

Congratulations

for 50 Years
of Service to the
Dairy Industry

★

White House
Milk Company, Inc.
MANITOWOC, WISCONSIN

Subsidiary of the Great A & P Tea Company

Congratulations

to the

American Dairy Science Assn.

on its

50th Anniversary

Regal Ice Cream Company

Division of
Safeway Stores, Incorporated

CONGRATULATIONS

on the

GOLDEN JUBILEE

from

THE CHICAGO DAIRY TECHNOLOGY SOCIETY

THE FIRST DAIRY TECHNOLOGY SOCIETY IN THE U.S.A.

Members of the American Dairy Science Association are cordially invited to attend our regular meetings on the second Tuesday of every month at 5:30 p.m. at the Furniture Mart, 666 LaSalle St., Chicago, Illinois.

FOR FURTHER INFORMATION WRITE TO:

Joseph Tobias, Secretary
103 Dairy Manufactures Building
University of Illinois
Urbana, Illinois

We Salute . . .

the **AMERICAN DAIRY SCIENCE ASSOCIATION** for 50 years of progress in research and teaching in the field of dairy science.

Beatrice Foods Co. firmly believes in the future of the dairy industry. We also appreciate the importance of basic research in making possible continued improvement in quality and the establishment of greater efficiency in methods.

Today the importance of dairying to the welfare of our people is commonly recognized. Ours is an active, dynamic, and progressive industry. The growth of our industry has been made possible by the cooperative efforts of the farmer, processor, distributor, research worker, teacher, and public official concerned with standards and sanitation. The guiding hand of the scientists in the over-all picture of progress is discernible, for which the members of A.D.S.A. should feel proud.

To the young men who are preparing themselves for careers in the dairy industry, we wish to extend our congratulations and best wishes. The industry needs your services. From your ranks will come most of tomorrow's leaders. Opportunity awaits those who are capable, and success will come to those of you who prove yourselves worthy.

The **AMERICAN DAIRY SCIENCE ASSOCIATION** blazes the trail leading to the economical production and distribution of high quality milk and milk products. Yours is an important function, and your responsibilities are great. You have made much progress since 1906. We wish you continued success in your efforts.

W. G. Karnes, President
Beatrice Foods Co.

Our 2,000th Member

Much credit is due to Lyman Rich of the Utah Agricultural College and his committee for their campaign to increase membership in the Association to at least 2,000. The goal was reached in May with the recording of the application of W. W. Echols of the Borden Co., Houston, Texas. The Association officers had decided ahead of time to honor the person who became the 2,000th member by giving him free membership.

W. W. Echols

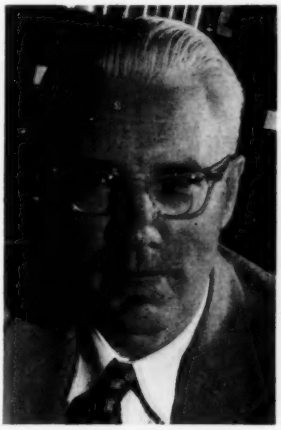
Mr. Echols was born in Dallas, Texas, and graduated from A. & M. College with a major in dairy husbandry in 1937. He became a Borden employee at that time and began his dairy career as a route salesman. In 1940 he was called to active duty with the Armed Forces, where he served as an artillery officer in the Asiatic-Pacific combat area. In 1946 he was released to inactive status and returned to the Borden Co. at Houston, where he is now employed as field superintendent.

Mr. Echols is active in civic affairs and is the father of three children, the oldest of whom is Charles, who plans to enroll at Texas A. & M. College this fall. Mr. Echols' hobbies are hunting and fishing. The Association is happy to welcome him as its 2,000th member.

Foreword

This issue of the Journal is designated as the Special Commemorative Number in recognition of the 50th anniversary of the founding of the American Dairy Science Association. It has been planned with thoughtful care in order that it might serve as a written historical monument to the entire dairy industry—a document which records the developments of dairying during the lifetime of our organization.

Because it constitutes a history of the dairy industry during a period of tremendous advances in science, technology, and education, this particular issue may be expected to have long-lasting value. We may well envision that when the year 2006 arrives, and with it the centennial of our Association, the historians of that day will refer to this commemorative publication in order to determine and evaluate the progress of the industry during the 50 years following 1956.



I. A. Gould

A great amount of personal effort and sacrifice has gone into the production of this special number on the part of the contributing authors and the editor and his staff. However, at no time was the question of financial remuneration raised by those involved and, thus, the successful completion of the project may be said to have resulted from "love of labor" and "unselfish support" by many persons.

This number has approximately three times the content of a regular issue and is costly, yet it is going to all members of the Association and subscribers without extra charge. Credit is due the companies and organizations that have purchased advertising space in this issue or have contributed anonymously and, by so doing, have helped greatly to finance the venture.

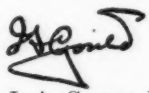
As one reads the various articles in this issue, he will be made aware of the great progress which has taken place in our industry during the past 50 years—and can take pride in it. At the same time, these historical articles emphasize indirectly the fact that the knowledge of any one period is the accumulation of the knowledge of the ages. Thus, the developments during the period 1906-1956 were made possible by researches and observations of earlier years. This humbling realization may help us to shun the temptation to glorify unduly the achievements that have been made during our lifetime and with which we are personally familiar and to deprecate and consider as elementary the findings of an earlier period. We must use care in order to evaluate from the vantage point of our present knowledge the importance of a particular scientific finding in those earlier days.

The success and growth of any industry depends upon continuous fundamental research and upon a supply of educated young men specifically devoted

to the industry's problems. The important role of our Association in the progress of the dairy industry is revealed by the fact that practically all of the basic research and the dairy education have been and continue to be the contribution of the active members of our group.

A dedicatory ceremony or the marking of an historical event encourages reminiscing and the glorification of past accomplishments. However, the main objective should be that the commemoration will serve both as a foundation and as an impetus for greater achievement and expansion in the future. On this premise then "Prepare for Tomorrow" might well be the main theme of our Association during this 50th anniversary year—as well as the basic reason for this historical number of the Journal.

Also, although there is no formal dedication assigned this issue, it would be appropriate to dedicate it to "the men of tomorrow." This would be proper, even though the pages in this issue and the activities of the Association this Golden Jubilee year give recognition and pay homage to the pioneers and others who have made our history so meaningful and so fruitful. These men deserve all that can be said or done for them—and more, too. However, the future of the dairy industry and of our Association is in the hands of the younger men of our group today—and of those who will come tomorrow. May we hope, therefore, that the history recorded in this issue will inspire and encourage them.

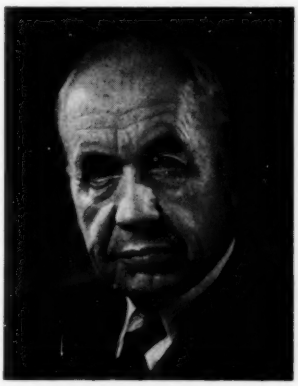


I. A. GOULD, *President*
The American Dairy Science Association

The Remaining Charter Members of A.D.S.A.

During the 1905 summer session of the Graduate School of Agriculture held at The Ohio State University, Professor W. J. Fraser of the University of Illinois suggested the idea of organizing a permanent "Dairy Instructors and Investigators Association." After some discussion it was decided that Professor Fraser should take up the matter with the various department heads throughout the country. If enough interest was shown, the organizational meeting was to be held in conjunction with the 1906 session of the Graduate School of Agriculture to be held on the campus of the University of Illinois. Of the group present for this first meeting six are living.

C. E. Lee. At this meeting a young staff member of the University of Illinois reported on studies he was making at that time on hand-separated cream and emphasized in his talk the need for trained men to pasteurize cream for buttermaking. This investigator, C. E. LEE, a graduate of the North Dakota Agricultural College, is now living at 2919 North Prospect Ave., Milwaukee, Wis. He was 81 years old on June 23, 1956. Lee left Illinois in 1909 to serve on the staff at the University of Wisconsin, where he received his M.S. degree. He served as assistant Dairy and Food Commissioner and Dairy Specialist for the State of Wisconsin from 1915 to 1920, when he joined the Gridley Dairy Co. (now a division of Borden's), Milwaukee, as manager of the laboratory and manufacturing operations. After retirement in 1940 he did consulting work until 1953. When recently asked his opinion of the future of dairying, Mr. Lee stated, "The outstanding progress has been largely due to the results obtained by research workers in every field affecting the industry. The future will bring even greater results. Cooperation in every field must continue as it has in the past."



C. E. Lee

C. F. Doane. Another paper presented at the 1906 Urbana meeting was that of C. F. DOANE, in which he called attention to the very limited amount of investigational work in progress along dairy lines as compared to what was being done in some of the other branches related to the agricultural industry. According to Mr. Doane, the belief was prevalent at this time that all the problems had been worked on and nothing of importance was left to be solved. Professor Doane spent 7 years at the University of Maryland working mostly with factors pertaining to the quality of milk. This was followed by 13 years with the U. S. Department of Agriculture, during which he worked mostly on cheese quality problems. Later he spent 5 years with a large dairy organization on the Pacific coast, again working on cheese. He is now retired and lives at 1510 N. 21st St., Salem, Oregon.

C. F. Doane

*Charles E. Thom.** Another cheese investigator attending the 1906 meeting was CHARLES THOM, a government worker from Washington, D. C., who stated, "The publication of a bulletin on the making of soft cheese is contemplated. The measure of success obtained justifies the belief that soft cheese making may be successfully undertaken upon a commercial scale in the United States at no distant day."

Thom was trained in botany and mycology and obtained his Ph.D. degree at the University of Missouri in 1899; he also did graduate work at Cornell during 1902-04. From 1904 to

*Just as the June Journal was going to press, word was received that Dr. Thom had passed away at his home May 24 as a result of a heart attack.

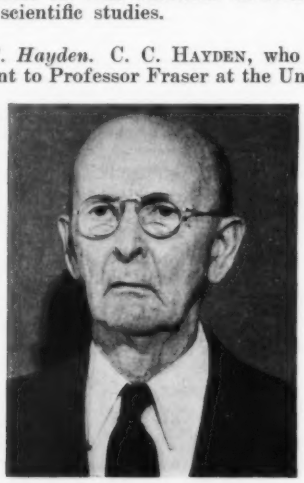
Charles E. Thom

1913 he was associated with the Bureau of Animal Industry, USDA, in charge of cooperative work in soft and fancy cheese making. He worked in cooperation with the Agricultural Experiment Station at Storrs, Conn., and from 1914 to 1927 he was in charge of the microbiological laboratory, Bureau of Chemistry. He then transferred to the Bureau of Chemistry and Soils, where he remained until 1934. From then until he retired in 1942 he was with the Bureau of Plant Industry. Dr. Thom is probably best known in the dairy industry for *The Book of Cheese*, of which he was co-author with Fisk. This text was one of the earliest books on the subject written in this country.

Dr. Thom, who was born on an Illinois farm Nov. 11, 1872, now lives at Bayles Hill, Port Jefferson, N. Y. Within the past year he lectured to student groups in the field of food technology at the Universities of Illinois and Wisconsin. He still maintains an active interest in scientific studies.

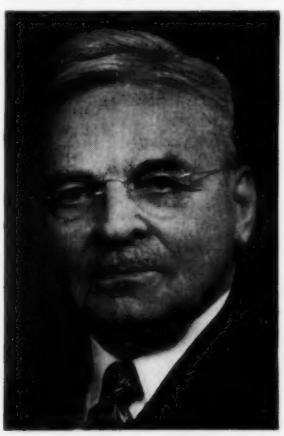
C. C. Hayden. C. C. HAYDEN, who was an assistant to Professor Fraser at the University of Illinois at the time of the first meeting, recently stated, "All of us can see that dairy conditions have improved greatly since 1906. Our cattle are better in production and health. Our equipment is far better. Our methods and our products are better. Our milk is a safe, wholesome food. One of the speakers at the Urbana meeting said that not enough knowledge regarding the principles underlying the various branches of dairying is at hand to give the subject scientific rank. Now our college and station dairymen are doing a great deal of scientific research, the results of which are published in scientific journals of high order, and departments the country over are being renamed Department of Dairy Science."

Professor Hayden was born on an Ohio farm Dec. 1, 1871, where he remained until he was 19 years old. He then entered Spring Arbor Seminary in southern Michigan, where he completed the equivalent of a high school course. In 1901 he received a B.S. degree in agriculture from The Ohio State University. This was followed by some commercial creamery experience and graduate training at the University of Wisconsin. He joined the Illinois staff in 1903, where he received his M.S. degree in 1909. In 1912 he was appointed head of the Department of Dairy Industry at the Ohio Agricultural Experiment Station, which position he held for 30 years. In 1942 he gave up the headship but remained as associate until his retirement in 1947. Professor Hayden is now living at his home at 438 N. Buckeye St., Wooster, Ohio.



C. C. Hayden

O. F. Hunziker. Even as far back as 1906, when OTTO F. HUNZIKER addressed the first meeting of the Dairy Instructors and Investigators Association, his name was closely associated with both the butter and condensed milk industry. At that time he was head of the Dairy Husbandry Department at Purdue Uni-

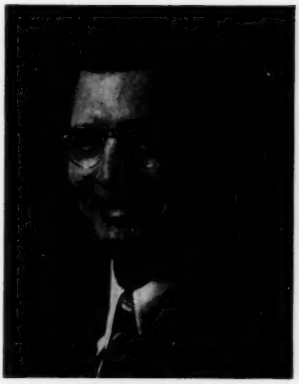


O. F. Hunziker

versity. Born in Zurich, Switzerland, in 1873, he obtained his early schooling in that country but came to the United States for his college work, graduating from Cornell University in 1900. He earned his M.S.A. degree at Purdue in 1901 and the D.Sc. in 1932. In 1916 he became manager of manufactures and director of the research laboratory for Blue Valley Creameries, in which capacity he served until 1939, when he resigned to become a dairy consultant. His books, *Condensed Milk and Milk Powder* and *The Butter Industry,* have been used as texts by several generations of college students and are widely used by industry throughout the world.

Dr. Hunziker has been the recipient of many honors and recognitions and ranks as one of the world's greatest dairy scientists. He has been an active member of A.D.S.A. since its beginning. Since his retirement from industry he has been active in revising his books and is a regular attender of national and international trade association meetings and expositions. Today he is living at 103 7th Ave., LaGrange, Ill.

E. S. Guthrie. At the first meeting in 1906 E. S. GUTHRIE of The Ohio State University described his experiences in herd improvement and sanitary milk production. This young man, who was born in Iowa in 1880, had just completed his B.S.A. degree at Iowa State the year before. He remained at Ohio until 1908, when he joined the staff at Cornell University, where he earned an M.S. degree in 1910 and a Ph.D. degree in 1913 in bacteriology. Though he became professor emeritus in 1948, he continues to be active in research in his favorite field—flavors in milk—and participates regularly in the annual meetings of the association he helped organize and to which he has given generously of his time during the past 50 years. He has been a productive research worker during his career, having published many articles in his field and a textbook on butter. Dr. Guthrie's mailing address remains Department of Dairy Industry, Cornell University, Ithaca, N. Y.



E. S. Guthrie

The fruitful manner in which the six remaining charter members of the original association have lived exemplifies the traditional spirit shown in the 50 years of progress made by A.D.S.A. It is because of the many fine contributions of these men and their associates through the years since 1906 that the dairy industry has been able to add so much to the health and happiness of our people and to the prosperity of our country. We are thankful for the guiding influence of our founders and the manner in which they inspired those of us who followed to translate that influence into continued progress for the dairy industry. To the younger generation about to take over we hand the torch; it carries with it honor and distinction but also humility and responsibility, for in the year 2006 another 50-year progress report will be due.

The Editor

WILBER JOHN FRASER

July 1, 1869 — April 16, 1945

Founder of the American Dairy Science Association

Fifty Years of the American Dairy Science Association

G. Malcolm Trout
Historian of the Association
Dairy Department, Michigan State University, East Lansing

The story of the American Dairy Science Association is intimately interwoven with the history of agricultural education in America and with the spectacular development of the dairy industry. Although the Morrill Act of 1862, signed by Abraham Lincoln, created Land-Grant colleges, the agricultural student enrollment at the turn of the 20th century was comparatively small.

G. M. Trout

The development of dairy training was hampered by a lack of scientific knowledge, suitable textbooks, and qualified instructors. The early agricultural and dairy training was centered around botany, chemistry, physics, and mathematics, for it was in those fields that texts for instruction were available. Both books and higher education in agriculture were sought in Europe.

The Hatch Act of 1887 authorized federal grants for the establishment of agricultural experiment stations. Soon, in research centers located generally at the state Land-Grant college, studies were being made on what seemed to be the most pressing problems. By 1900, many fundamental discoveries in dairying had been introduced. The principles of pasteurization, condensing, separating, acidity and fat testing, refrigeration, and homogenization had been laid down.

Fifty years ago the dairy industry was undergoing tremendous change. The introduction of the Babcock test and the farm cream separator gave an impetus to farm cream production and the establishment of centralizers and creameries. Milk depots were distributing milk, and cheese factories were increasing in numbers.

As a result of the increase in number of dairy plants, trained men were needed. The demand grew for special dairy departments and separate dairy curricula in state universities. The need for specific training in dairy production and dairy manufactures was recognized. Several schools, Cornell, Iowa, Wisconsin, Purdue, Pennsylvania, Ohio, Missouri, Minnesota, Ontario, and Illinois, gave instruction in dairying. The foregoing was the general status of dairy instruction and research facilities when the American Dairy Science Association was founded in July, 1906.

Organization and Early Development

The original name of the Association was "National Association of Dairy Instructors and Investigators." Illinois Agricultural Experiment Station Circular 111 gives the following concise information relative to the establishment of the organization:

> "A meeting of the heads of Dairy Departments and Dairy Investigators was called by Professor W. J. Fraser, of the University of Illinois, July 17, 1906, while the Graduate School of Agriculture was in session at that institution, and the National Association of Dairy Instructors and Investigators was organized with eighteen [sic] members enrolled. Professor Fraser was made Chairman of the meeting, and C. B. Lane of the Department of Agriculture, Secretary and Treasurer."

A constitution was adopted embodying only 98 words and providing for membership of dairy instructors and investigators (of college rank) from the agricultural colleges, experiment stations, and dairy divisions of the United States and Canada upon payment of fifty cents to the secretary-treasurer.

Before the 3-day session ended, 17 papers were read; visits to the dairy barn and university farm were made; the major dairy problems of the day were discussed; seven new committees, in addition to the executive committee composed of the officers of the association, were appointed "to make a careful study of various subjects, looking to more uniform and efficient work"; the report of the Committee on Permanent Organization was adopted; and a noncharter, nonattending member from Cornell University was elected as the first president of the newly formed organization.

The discussion at the meeting was brief. It included recognition by Professor Eckles of the organization's responsibility in forming associations to test cows, something the farmer would not do for himself, and arrangements for a second meeting, "about July 1st" the next year. Appreciation was expressed to Professor Fraser, who had taken the initiative to call the group together and who served as chairman of the first meeting.

Considerable thought had been given previously to an organization of the dairy instructors of the several colleges. C. C. Hayden, Ohio, charter member, writes:

> "The 'Association' originated at a session of the 'Graduate School of Agriculture' held one year earlier (1905) at the Ohio

CHARTER MEMBERS
NATIONAL ASSOCIATION OF DAIRY INSTRUCTORS AND INVESTIGATORS
JULY, 1906

Front Row: C. C. Hayden, Illinois; J. W. Decker, Ohio; C. F. Doane, U. S. Dairy Div.; W. J. Fraser, Illinois; H. A. Hopper, Illinois. *Middle Row:* J. M. Trueman, Illinois; C. H. Eckles, Missouri; Ed. H. Webster, U. S. Dairy Div.; A. C. True, Div. Office Expt. Stats.; H. H. Dean, Canada; C. B. Lane, U. S. Dairy Div.; F. R. Rasmussen, Iowa. *Back Row:* C. E. Lee, Illinois; O. F. Hunziker, Ind.; E. S. Guthrie, Ohio; H. E. Van Norman, Penna.; Charles Thom, U. S. Dairy Div.; E. Davenport, Dean, Ill.; B. D. White, U. S. Dairy Dept.

State University. Professor Fraser of Illinois and a few other dairymen got the idea and discussed it. Professor Fraser was asked to call a meeting of those interested. The call went out to meet at Illinois with the Graduate School of Agriculture, and a program was prepared. . . ."

The second annual meeting of the new Association was held in Chicago, October 11, 1907, in connection with the National Dairy Show. The attendance was meagre. Within 16 months of the first meeting, the underlying principles for successful successive meetings as laid down at Urbana, namely, that the meeting should be held during the summer and on a college campus, had been ignored. Consequently, the prevailing enthusiasm at Urbana was lacking in Chicago. Twenty-one attended the banquet, which was followed by the business meeting; the president made his address; reports from six committees were received and discussed; and officers for the next year were elected. The first president, Raymond A. Pearson of Cornell University, and also vice-president Erf and secretary-treasurer Lane were reelected to succeed themselves for another year. Not until 1931 were the by-laws of the constitution changed to limit the presidency to one year.

The third annual gathering of the members of the Association (meanwhile changed to "Official Dairy Instructors' Association") was on the campus of Cornell University, July 22, 1908. Membership had increased from the 17 charter members to 69 from 26 states, the District of Columbia, and Canada. This third conference had certain characteristics which destined it to become of historical significance. In the first place, membership was up, attendance was relatively high, and the interest was good.

Second, the president serving his second year confined his address to a few remarks, emphasizing the need of interesting competent young men in the dairy industry. Third, the program consisted not of topic papers by individuals, which featured the first meeting, but of thorough, thought-provoking, action-stimulating committee reports. Fourth, these committee reports were to become in large part the guide for the thinking of the members of the Association for years to come. With possibly one exception, complete reports were presented on the following subjects: "Dairy score card"; "National dairy register of merit"; "Our relations to the National Dairy Show"; "Courses of instruction"; "Experimental work: production"; "Experimental work: manufactures"; "Standards for dairy products"; "Extension work"; "Extension work in the United States"; "Official testing"; "Cooperative work"; and "Cow test associations."

Already the leadership of the Association was manifesting itself in the development of score cards, standards for products, rules for dairy cattle judging contests, testing and identification of dairy cows, instruction and research, and even in dairy extension, which was not to be recognized and provided for officially by the United States government until the passage of the Smith-Lever Act of 1914.

As a result of the Cornell conference and through the activity of a segment of the new organization, the first college dairy cattle judging contest was set for December 3, 1908. This contest has been held virtually every year since its establishment.

Unfortunately, the Ithaca conference was the last of the official, summer, on-college-campus meetings to be held for 19 years.

The name of the organization and its changes. During the past 50 years, the Association has lived under three names: *(a)* the "National Association of Dairy Instructors and Investigators"; *(b)* "Official Dairy Instructors' Association"; and *(c)* the "American Dairy Science Association."

The first name chosen, "National Association of Dairy Instructors and Investigators," lacked brevity and specificity, indicated geographical scope of the United States, and implied membership for educators and research workers only.

The chartered name was short-lived. In the address of first-president Raymond A. Pearson at the second annual meeting he stated:

> "The name of our organization is not descriptive of its character. We call it 'The National Association of Dairy Instructors and Investigators.' Yet, some of our members represent the great dairy interests of Canada. It is then, strictly speaking, not a national organization. The name may be criticized, also, because it is cumbersome. I would like to suggest as a new name, 'Official Dairy Instructors' Association.' This is conveniently short. It would not exclude investigators, as they give instruction indirectly. If it is desired to define geographical limits, this can be done in the constitution."

This suggestion for a name change was accepted and the revised constitution (148 words) of 1908 stated—"The name of this organization shall be the Official Dairy Instructors' Association." This name persisted for the next 9 years.

At the 11th annual meeting of the Official Dairy Instructors' Association in Springfield, Mass., 1916, exception was taken to the name of the Association because the word "Official" suggested police activities and the word "Instructor" seemed to limit the membership unduly. After some discussion the following action was taken:

> It was moved and seconded that the change of the name of the Association be left to the President [Stocking], Secretary [Mortensen], and Professor Harding, but before a name could be adopted a vote of the membership be made.

Suggestions for names were solicited and submitted to the entire membership for vote.

More than 10 names were proposed: five of them employed the term "Instructors," and a sixth title used the word "Instruction." Nevertheless, the weighted value of the ballot showed that the "American Dairy Science Association" was by far the predominating first choice. Therefore, the committee, exercising the power given at the Springfield meeting, reported as follows:

> "As the result of the action of the Society at its last meeting, and as the result of the vote which has just been taken, the 'Official Dairy Instructors' Association' has now become the 'American Dairy Science Association.'"

Eras in the Life of the Association

The first 50 years of the American Dairy Science Association might well be divided into four distinct periods: *(a)* the foundation period; *(b)* the dark era; *(c)* the Journal-establishment years; and *(d)* the summer-meeting-on-college-campus period. Each of these periods seemed to have a distinct beginning, which set the era off from its predecessor and often gave impetus to the Society.

The foundation period. This period extended from 1906 to 1908, inclusive. Two of the first three annual meetings were held on college campuses. The other meeting was held in connection with the National Dairy Show. Enthusiasm prevailed when the meetings were held with a suitable college background but was lacking when the meeting had to compete with the diverging interests of the cattle show.

First reinstated summer-on-college-campus meeting, East Lansing, June, 1927.

Nevertheless, a basic organization was effected, a constitution was drawn up, committees were appointed, the most important dairy problems were spelled out, and a guiding prophetic presidential address was made. Fortunately, the interest engendered and problems tackled during the short span of life of the new organization were sufficient to carry it through the rather uneventful 7-year period which followed.

The dark era. This period is so named because little published information or records have survived. Apparently, the annual meetings were held in conjunction with the National Dairy Shows at Milwaukee, Chicago (5 years in succession), San Francisco (Panama-Pacific International Exposition), and Springfield. In addition, unofficial summer conferences were held at the Michigan Agricultural College, East Lansing, in 1912, and at the Massachusetts Agricultural College, Amherst, in 1916, in connection with the biennial meetings of the Graduate Schools. Nevertheless, interest in the Official Dairy Instructors' Association seemed to be second to that accorded the livestock champions. Professor C. C. Hayden, charter member, writes in part:

> "My memory is that those early meetings held at the National Dairy Show were not very well attended (except the banquet) and the attendance was irregular. Often interest in some event at the show would almost break up the meeting. The early meetings were largely taken up by committee reports."

Professor E. S. Guthrie, charter member, recalls:

> ". . . Through those years you refer to as a 'dark era' we did not accomplish much at our conventions. *We did, however, hold together.*"

Apparently, this was a period of indecision. Despite the early judgment to hold the annual meeting "about July 1st" and despite the conflicting interests of the National Dairy Show, the October conference had a magnetic attraction hard to overcome. J. H. Frandsen, fourth president, in his presidential address October 28, 1914, expressed concern over the time and place of holding the annual meeting:

> "The Association might also with profit settle at this time whether it desires a meeting held in the midst of vacation during the summer with no disturbing influence except its effect on vacation, or whether it prefers its business done as at this time in connection with the Dairy Show."

During this period, also, the society was becoming policy-conscious. Frandsen, in his presidential message, envisioned:

> "In closing, I can but repeat that the dairy industry which we represent is destined to become, if, indeed, it is not already, one of the leading industries of the country. It should be our aim and purpose as representatives of this industry to exercise such an influence as will be of lasting value in framing the policies upon which its future development must depend. In the past we have been criticized for our lack of agressiveness. It has been said that often we were content to let others fix our policies and standards, when as a matter of fact we are in every way equipped to shape most satisfactorily the standards and policies that will work for the ultimate good of the dairy industry."

Journal-establishment years. This span of time extended from 1917 to 1926, inclusive. The founding of the *Journal of Dairy Science* was the high light and uniting force of this period.

Although the annual meetings continued to be held at the time and place of the National Dairy Show, the eyes of all the members of the American Dairy Science Association were focused on the new journal. The publication gave a sense of direction, a worthwhileness, and an incentive-to-being to the Association. Having survived its birth and beginning years, the Association needed a stimulus and uniting force beyond the prosaic, poorly attended, and more or less uninteresting annual meetings. The *Journal of Dairy Science* furnished that needed stimulus.

Summer meeting-on-college-campus period. This fourth period in the life of the American Dairy Science Association extends from 1927 to the present time. With only two exceptions in the last 29 years (Washington, D. C., 1929; Chicago, 1945) the annual meetings were held on college campuses. After more than a score of years, the dream of the charter members that the annual meetings be held during the summer and on a college campus came to realization. The renewal of the summer meetings on college campuses and the success of the first reinstated meeting must be credited in large part to President J. B. Fitch of Minnesota, host O. E. Reed of Michigan State, and Vice-President J. M. Sherman of Cornell.

At the twenty-first annual meeting of the Association held in the Book-Cadillac Hotel, Detroit, Oct. 7-9, 1926, a resolution was adopted asking the Executive Committee to consider the advisability of holding a summer meeting of the American Dairy Science Association in order to avoid the conflicting activities in connection with the National Dairy Show. Accordingly, the Executive Committee voted to hold a summer meeting at the Agricultural College, East Lansing, Mich., June 22-24, 1927. Only six who attended the 1908 meeting at Cornell were present at the East Lansing meeting. During this 3-day meeting the subjects were presented enthusiastically to an interested audience. Before the first day had ended, the general feeling prevailed that the meeting was an

outstanding success. After much discussion, the Executive Committee proclaimed this as the official annual meeting. Also, the officers were authorized to plan for a summer meeting in 1928 as the annual meeting. These actions were approved by the convention on June 23, 1927. At last the American Dairy Science Association had found itself.

An unplanned feature of the 1927 meeting, acclaimed at the time by some and viewed with alarm and misgivings by others, was the using of the annual meeting as a vacation for the family. A few members dared to bring their wives with them to the 1927 summer meeting. The camaraderie of the wives soon convinced the skepties that the summer meetings offered family group vacation possibilities not heretofore considered. Inclusion of the families as a part of the annual summer meetings foretold the future success of the meetings.

The Journal of Dairy Science

Perhaps no single introduction has so influenced the development and world status of the American Dairy Science Association as the establishment of the *Journal of Dairy Science* in 1917. This was a pioneering step. Even *Le Lait,* the French scientific dairy journal, did not make its appearance until 3 years later.

The Journal had been in the planning state for 4 years and was the dream of Professor Julius H. Frandsen, then of Idaho, and the fourth president of the Association. In his 1913 presidential address before the Official Dairy Instructors' Association, he extolled the virtues of a publication devoted exclusively to articles on dairying. A committee was appointed and by 1916, at the Amherst and Springfield meetings, plans were effected whereby the Executive Committee was empowered to appoint an editor-in-chief and approve a publication contract with Williams and Wilkins Company, Baltimore, for publishing a bimonthly journal.

Professor Frandsen was elected editor. Through him the Journal was guided, nurtured, and made a vital force of the Association. The first issue was delayed, pending the change in the name of the organization. When the name became the American Dairy Science Association, Frandsen reported, ". . . It seems particularly fitting that the official organ of this Association should be known as the Journal of Dairy Science." This name has remained.

In the light of nearly 40 successful years of Journal publication it is of interest to record that at the time the Journal was established sour notes were to be heard; one of the members expressed the opinion that a journal was not needed because the trade journals would publish important papers without cost.

Volume I. The first issue of the Journal was published under the date of May, 1917. The leading article was the dedicatory, 15-page address of the Association's first president, R. A. Pearson, who meanwhile had become president of Iowa State College. The occasion was the dedication of the University of Nebraska's new dairy building, the Dairy Department being headed by Professor Frandsen.

Financial problems and emphasis on a scientific publication. President Eckles, in an informal address at the 17th annual meeting held at University Farm, St. Paul, Oct. 10, 1922, urged greater support of the *Journal of Dairy Science,* which was being carried by the publishing company at a loss. Also, Williams and Wilkins Company, the publishers, emphasized the need for stronger support for the Journal.

At this time, the editorial board was confronted with the problem of competitive publications, which had not been a matter of concern previously. This made it necessary for the Journal to consider carefully its function and scope of coverage. The editorial board, in 1922, after five successful Journal years, took the position that:

> "The *Journal of Dairy Science* can render the best service to the Dairy Industry of America and is making no mistake by continuing its present policy of being preeminently a scientific publication. However, the Journal is yet in its childhood, and most of its development lies in the future."

Accordingly, the editors adopted a policy of more rigid cutting, limiting the length of manuscripts, keeping to dairy subject matter, and accepting only heretofore nonpublished manuscripts. By 1924, editor Frandsen was caught up on material and appealed for more high-grade articles. Emphasis was being placed on quality of papers.

Dahlberg elected editor. With the completion of the January, 1928, issue of Volume XI, Professor Frandsen turned over the editorship of the Journal, after having guided its first 10 years, to A. C. Dahlberg of the New York Agricultural (Geneva) Experiment Station. Under editor Dahlberg, the Journal was to have its adolescent growth. Within the next 10 years the Journal was to: *(a)* become the property of the Association; *(b)* become a monthly publication; *(c)* include abstracts of dairy literature; and *(d)* be recognized throughout the dairy world as the leading scientific dairy journal.

The Executive Committee at the 1929 Washington, D. C., meeting decided that some effort should be made to extend the field of the Journal and requested Dr. Dahlberg to plan for such extension. He did well, for at the 28th annual meeting at Urbana, 1933, the Journal Management Committee was authorized to put the Journal on a 12-issue basis for 1934 and, if needed, to use up to $4.00 of the membership fee for the Journal. In 1936 the abstracting service was included.

Sutton becomes editor. After editor Dahlberg's resignation, T. S. Sutton, Ohio, was ap-

pointed editor of the Journal, effective July 1, 1938. The previous editors, Frandsen and Dahlberg, had been elected by the members, but the 1934 revision of the by-laws of the Association provided that this position be appointive.

Editor Sutton served faithfully and well from July 1, 1938, until Jan. 1, 1946, maintaining the high standards previously established for the Journal. During his regime the program for the review articles, started by Dr. Dahlberg, was carried out most effectively. Comprehensive review articles were sought and encouraged. The first review article was published in the October, 1938, issue. To January 1956, 38 such articles had been published, requiring 1,038 printed pages listing a total of 5,573 citations. The Journal was gradually increasing in size and by 1940 contained four times as many words as did the volumes published prior to 1932.

Mounting teaching and research responsibilities forced editor Sutton, after 7½ years as editor, to tender his resignation effective Dec. 31, 1945. It was accepted by the Board with reluctance.

Nelson becomes fourth editor. After editor Sutton's resignation, the Executive Board chose F. E. Nelson, Iowa State College, to take over the editorial post of the Journal as of Jan. 1, 1946. Dr. Nelson not only maintained the high scientific standard of the Journal articles but enlarged the abstracting service. More abstractors were added to give greater dairy literature coverage. By changing the format and type size of the Abstract Section in January, 1949, more abstracts were printed per page without appreciably added costs. Dr. Nelson served as the editor of the Journal from January, 1946, through December, 1952. The Executive Board accepted his resignation, effective December 31, 1952, "with regrets."

Many journalistic introductions under editor Tracy. P. H. Tracy, of the University of Illinois, was appointed editor of the Journal, effective Jan. 1, 1953. Promptly, he began the introduction of a series of new features: "People and Events" with its pioneers in the dairy industry, news items, editorials, and pertinent happenings, appeared in the January issue, 1953; "Letters to the Editor" and "Our Industry Today," containing articles written in laymen's language on current problems, were added in November. At the annual meeting in 1953, the Executive Board had authorized expansion of the so-called "popular" section rather than attempt publication of a second journal.

These additions were presented under separate headings at the end of each issue but were paged as part of the Journal proper. In no way did the new features detract from the regular scientific articles, and the high standards of the Journal were maintained. By contrast, these additions have enhanced the technical section and have increased reader interest. In 1955 a "Technical Notes" section was added to the scientific portion to provide a place for short articles and progress reports. In January, 1956, a "Student Chapter News" section was added as a regular feature.

These introductions were the culmination of many years of consideration by the Executive Board on ways to make the Journal more acceptable to nonscientific people. The matter had been discussed at some of the general business meetings of the Association, and considerable interest was manifested on at least two different occasions. Recommendations were made either *(a)* to modify the Journal per se or *(b)* develop a publication of a more popular nature. As a result of this interest the "News Letters" came into existence.

Editor F. E. Nelson had introduced a separate Newsletter, which was mailed to all the Association members and affiliates in April, 1947. This was followed by a second issue in June. During 1948 the Newsletter was discontinued. Despite its short life, the 4-page, trimonthly Newsletter did bring out the fact that members were interested in current, personal news notes.

Although the venture failed, there was considerable feeling that something needed to be done to gain greater acceptance of the Journal. This was a matter of great concern to the Executive Board and, at the time of Dr. Tracy's appointment, the Board went definitely on record as favoring the development of a new "section" in the Journal and Dr. Tracy was instructed to proceed accordingly. Also—at that time—an office of "Assistant Editor" was established for the purpose of making possible an expansion of the Journal. E. E. Ormiston of Illinois was selected by Dr. Tracy to be assistant editor for one year. In the subsequent year, W. O. Nelson of Illinois was appointed as abstract editor, and the position of assistant editor was abolished. The development of the "News Letter" and of the "New Section" arose from the same desire—to increase the influence of the Journal and to make it more acceptable to those in the commercial field.

Surely today, one may say as did Eckles in 1922, "If our organization had never done anything else but establish this journal, our efforts would be well repaid."

Incorporation of the American Dairy Science Association

Apparently, when the Society was founded in 1906, little thought was given to incorporation for the purpose of contracting and doing business. Even the introduction and publication of the *Journal of Dairy Science* in 1917 brought no immediate need of incorporation. Agreement was effected with Williams and Wilkins Company, Baltimore, whereby they published and mailed the Journal to the members of the Association. By so doing they owned the Journal "lock, stock, and barrel." Even the mailing list was not available to the Association.

When A. C. Dahlberg was elected editor in 1927, the *Journal of Dairy Science* was copyrighted by the Williams and Wilkins Company. The company solicited advertising, set the subscription price, kept the mailing list, handled all funds, and maintained the financial records.

At the 26th annual meeting at Davis, Calif., in 1931, the Executive Committee was authorized to incorporate when and in such manner as might seem most desirable to the welfare of the Association and to the publication of the *Journal of Dairy Science*.

President Ellenberger then appointed the first Journal Managment Committee, consisting of O. F. Hunziker, R. R. Graves, and A. A. Borland. With editor Dahlberg, they studied the Journal situation. They found it necessary to change the constitution in order to have the editor and secretary appointed and to permit the Association to operate its own Journal. This was done by mail ballot during the winter of 1931, approving Article 6, which provided for appointment of the secretary-treasurer and editor by the Executive Committee. The revised constitution was approved in 1934.

The Journal Management Committee formulated a plan to handle the Journal, but the publishers were not interested and advised that to do as desired the Association would need to buy out their interest. Meanwhile, the committee proceeded to incorporate under the laws of the District of Columbia, letting the old American Dairy Science Association become extinct. The American Dairy Science Association, Inc., began to publish the *Journal of Dairy Science* under its ownership and management and the Science Press Printing Company, Lancaster, Pa., was selected to do the printing.

Some journal-ownership problems. One of the Association's first objectives was to get out of debt and build up a financial reserve equal to one year's income. Debt and lack of financial reserve had plagued the Association for years. When Dahlberg became editor, J. M. Sherman was secretary. Because of the financial condition of the Association they agreed to use only $200 for each office per year for secretarial service and to donate their own services. As a result of this economy and increased sources of revenue, a financial reserve of approximately $1,200 was developed in two years.

The Executive Committee strove to increase membership to 400. Then the Committee considered the suggestion that a business manager or secretary be hired and be placed in the office of the editor. However, the business was still too small to make this possible. In 1936, R. B. Stoltz was appointed secretary.

The Association now owns its Journal and has a fine financial reserve.

Some Journal of Dairy Science "Extras"

Although the *Journal of Dairy Science* is primarily a scientific publication, it has furnished during its 39 years of existence many other features not always fully appreciated by the members of the American Dairy Science Association. The history of the Association would be incomplete without due recognition of them and their development.

Abstracts of dairy literature. Dairy science abstracts have been a feature of the *Journal of Dairy Science* since 1936. Credit is due O. F. Hunziker for his foresight and persistence in making this feature a major, useful part of the Journal. But others, H. F. Judkins, R. C. Hibben, R. B. Stoltz, R. E. Little, A. A. Borland, and editor Dahlberg, played most important roles also in the publication of "Abstracts of Literature on Milk and Milk Products," as a separate section of the Journal.

The situations leading to this Journal innovation must be recounted more fully. The International Association of Ice Cream Manufacturers since 1927 and the International Association of Milk Dealers since 1931 had collected, published, and sold abstracts yearly. Dahlberg was the abstract editor for both of these Associations. Having been elected editor of the Journal also, he found the editorship load exceptionally heavy and conceived the idea that his load might be lightened, and at the same time the value of the *Journal of Dairy Science* might be enhanced, if the American Dairy Science Association published the abstracts in cooperation with the two International Associations. The idea appealed to O. F. Hunziker, chairman of the Journal Management Committee, who promptly promoted such a consolidation. The final arrangements that made the consolidation possible were suggested largely by R. C. Hibben, secretary of the International Association of Ice Cream Manufacturers. Hibben proposed, and the milk dealers agreed, that the two Associations would guarantee a definite specified increase in the American Dairy Science Association membership. However, should this increase fail to materialize, they would make up any deficit incurred in the publication of the abstracts. This guarantee swung the Board in favor of the abstract service.

It should be borne in mind that the publication of these abstracts in the Journal was a joint responsibility of the three groups. The two International Associations solicited membership for the American Dairy Science Association from their own mailing lists. They designated members from their own associations to serve on the editorial board for the review of all abstracts prior to publication. The names of these editorial board members appeared on the page of the *Journal of Dairy Science* immediately preceding the abstracts until February, 1952.

At the 1936 meeting, editor Dahlberg reported that the abstracting service included publications of all the state and federal experiment stations, several European experiment stations and 49 journals. By 1949, 57 abstractors were abstracting 99 journals.

Indexes. The Executive Board in 1939 authorized the indexing of the first twenty volumes of the *Journal of Dairy Science.* This 20-year index, compiled by Harold Macy, Minnesota, was published in 1942. Later, steps were taken toward publication of the 10-year index of the *Journal of Dairy Science* for the years, 1937 to 1946, inclusive. Thanks again to Dr. Macy, the decennial index, covering Volumes XXI-XXX, was ready for printing at the time of the 1952 meeting.

Structural Development of the Association

The constitution. The constitution and by-laws of the American Dairy Science Association have undergone marked changes during the past 50 years. The size and specificity of later revisions of the constitution are in marked contrast to the earlier ones. The detail and length reflect the diversified interests of the members. The development and revision of the constitution and by-laws have required much study. To C. H. Eckles and M. Mortensen must go the credit for the first major changes.

At the 25th annual meeting in Ames, Iowa, the desirability of further revisions was discussed. Again, C. H. Eckles was asked to serve as chairman of a study committee and to name his own assistants. Unfortunately, death soon claimed Dr. Eckles, and the task was unfinished. However, Article 6 of the by-laws, specifying the term of office and the composition of the Executive Committee, was adopted in 1931. The chronological development of the constitution has been as follows:

Year	*Length*	*Feature*	*Chairman*
1906	96 words	Organizational	———
1908	148 words	Name change	———
1920	3½ pages	Name change, organization and amplification	C. H. Eckles
1922	3½ pages	Revision and amendments	M. Mortensen
1925	3½ pages	Revision	———
1931	¼ page	Articles	R. R. Graves
1934	4½ pages	By-laws	C. L. Roadhouse
1938	3½ pages	By-laws	S. M. Salisbury
1942	4½ pages	Revision	G. M. Trout
1955	2½ pages *	Revision	E. L. Jack

* Double column

Officers of the Association. The 1955 revised constitution and by-laws state that the officers of the American Dairy Science Association shall be "president, vice-president, secretary-treasurer, journal editor, and seven directors, one of whom shall be the immediate past president." These officers constitute the Executive Board, the governing body of the Association.

The names and tenure of the officers of the Association since its founding are of historical interest. W. J. Fraser was chairman of the organizational meeting in 1906 at which R. A. Pearson was elected the first president. His tenure of office was 2 years. With few exceptions up to 1930, when the actual tenure of office became 1 year (credit to J. M. Sherman), the presidents served a 2-year period. W. A. Stocking served 3 years, from 1916 to 1918, inclusive. These 2-year terms prevailed despite specification in the 1920, 1922, and 1925 constitutions that the term of the president should be for 1 year. C. H. Eckles, who followed Pearson as president during 1908 and 1909, again served the Association as president in 1921 and 1922, a total of 4 years, which was the longest service as president given by one man. In all, the Association has had 39 presidents (Table 1). Thirteen secretary-treasurers have served the Association. C. B. Lane was the first secretary-treasurer, serving 4 years, and R. B. Stoltz had the longest tenure of office—13 years.

A Board of Directors consisting of three members serving 1, 2, and 3 years, respectively, was first elected in 1933. As each term expired, new directors were elected for a 3-year period. In 1936, the number of directors was increased to seven, six to be elected as such and the seventh to be the retiring president. The names of the directors are presented in Table 2.

Section organization. Professor Mortensen, in his presidential address Oct. 11, 1920, strongly advised that the annual meetings of the Association be held in sections as follows: (1) breed associations, (2) dairy production, (3) dairy manufacturing, and (4) extension work. During the years that have followed, five sections have been recognized: Official Testing and Advanced Registry; Production; Manufacturing; Extension; and Economics. The Official Testing and Advanced Registry Section and the Economics Section no longer appear as separate sections on the program of the annual meetings. The officers of each section are presented in Table 3.

Organization of sections was provided for by the constitution adopted in 1920. Three section meetings were thus authorized: (1) dairy production; (2) dairy manufactures; and (3) official testing. Eckles reported in 1921 that at the annual meeting of the Association of Extension Workers in Dairying (heretofore not affiliated

TABLE 1

The officers of the American Dairy Science Association, by years

Meeting	Location of annual meeting	Date	President	Vice-president	Secretary-Treasurer
1st	Urbana	1906	R. A. Pearson*	Oscar Erf*	C. B. Lane*
2nd	Chicago	1907	R. A. Pearson	Oscar Erf	C. B. Lane
3rd	Ithaca	1908	C. H. Eckles*	H. E. Van Norman*	C. B. Lane
4th	Milwaukee	1909	C. H. Eckles*	H. E. Van Norman	C. B. Lane
5th	Chicago	1910	O. F. Hunziker	W. J. Fraser*	W. A. Stocking*
6th	Chicago	1911	O. F. Hunziker	W. J. Fraser	W. A. Stocking
7th	Chicago	1912	J. H. Frandsen	F. Rasmussen*	W. A. Stocking
8th	Chicago	1913	J. H. Frandsen	F. Rasmussen	C. W. Larson*
9th	Chicago	1914	F. Rasmussen*	W. A. Stocking*	C. W. Larson
10th	San Francisco	1915	F. Rasmussen		C. W. Larson
11th	Springfield	1916	W. A. Stocking*	A. C. Anderson*	M. Mortensen*
12th	Columbus	1917	W. A. Stocking	A. C. Anderson	M. Mortensen
13th	Columbus	1918	W. A. Stocking	M. Mortensen*	N. W. Hepburn*
14th	Chicago	1919	A. C. Anderson*	M. Mortensen	N. W. Hepburn
15th	Chicago	1920	M. Mortensen*	O. E. Reed	N. W. Hepburn
16th	St. Paul	1921	C. H. Eckles*	O. E. Reed	N. W. Hepburn
17th	St. Paul	1922	C. H. Eckles	A. A. Borland	J. B. Fitch
18th	Syracuse	1923	A. A. Borland	O. E. Reed	J. B. Fitch
19th	Milwaukee	1924	A. A. Borland	O. E. Reed	J. B. Fitch
20th	Indianapolis	1925	O. E. Reed	H. F. Judkins	J. B. Fitch
21st	Detroit	1926	O. E. Reed	H. F. Judkins	G. C. White*
22nd	East Lansing	1927	J. B. Fitch	J. M. Sherman	G. C. White
23rd	Madison	1928	G. C. White*	A. C. Baer*	J. M. Sherman
24th	Washington	1929	G. C. White	H. A. Ruehe*	J. M. Sherman
25th	Ames	1930	J. M. Sherman	H. C. Jackson	R. R. Graves
26th	Berkeley-Davis	1931	H. B. Ellenberger	C. E. Wylie	R. R. Graves
27th	Lexington	1932	E. L. Anthony	R. B. Stoltz*	R. R. Graves
28th	Urbana	1933	H. C. Jackson	R. B. Stoltz	R. R. Graves
29th	Ithaca-Geneva	1934	R. B. Stoltz*	C. L. Roadhouse	R. R. Graves
30th	St. Paul	1935	C. L. Roadhouse	H. A. Ruehe*	R. R. Graves
31st	State Col., Pa.	1936	H. A. Ruehe*	R. R. Graves	R. B. Stoltz*
32nd	Lincoln	1937	R. R. Graves	H. W. Gregory	R. B. Stoltz
33rd	Columbus	1938	H. W. Gregory	E. Weaver	R. B. Stoltz
34th	Moscow-Pullman	1939	E. Weaver	E. S. Guthrie	R. B. Stoltz
35th	W. Lafayette	1940	E. S. Guthrie	H. W. Cave*	R. B. Stoltz
36th	Burlington	1941	H. W. Cave*	H. F. Judkins	R. B. Stoltz
37th	East Lansing	1942	H. F. Judkins	H. P. Davis	R. B. Stoltz
38th	Columbia	1943	H. P. Davis	A. C. Dahlberg	R. B. Stoltz
39th	Columbus	1944	A. C. Dahlberg	A. C. Ragsdale	R. B. Stoltz
40th	Chicago	1945	A. C. Ragsdale	J. A. Nelson	R. B. Stoltz
41st	Ames	1946	J. A. Nelson	F. Ely	R. B. Stoltz
42nd	Guelph	1947	F. Ely	P. H. Tracy	R. B. Stoltz
43rd	Athens	1948	P. H. Tracy	W. E. Petersen	R. B. Stoltz
44th	St. Paul	1949	W. E. Petersen	G. M. Trout	P. R. Ellsworth
45th	Ithaca	1950	G. M. Trout	R. B. Becker	P. R. Ellsworth
46th	Knoxville	1951	R. B. Becker	H. A. Bendixen	P. R. Ellsworth
47th	Davis	1952	H. A. Bendixen	H. B. Henderson	P. R. Ellsworth
48th	Madison	1953	H. B. Henderson	W. V. Price	P. R. Ellsworth
49th	State Col., Pa.	1954	W. V. Price	L. A. Moore	P. R. Ellsworth
50th	East Lansing	1955	L. A. Moore	I. A. Gould	T. D. Harman
51st	Storrs	1956	I. A. Gould	C. F. Huffman	H. F. Judkins

* Deceased

with the American Dairy Science Association) this organization voted to join the American Dairy Science Association.

By majority membership vote the Executive Committee was asked in 1928 to create a new section of the Association to be known as the Dairy Economics Section. Five years later, at the Urbana, Ill., meeting, a motion was adopted that the Economics Section be abolished because it was not functioning.

Sporadic attempts have been made to establish a section of dairy instruction, but major interest seemed to be lacking. A 9-paper college instruction program was presented at the 1932 meeting, held at Lexington, Ky. President Roadhouse in 1935 urged heads of departments who had new curricula, innovations, or modifications of teaching practices to have them presented and discussed at the 30th annual meeting, to be held in St. Paul. This resulted

TABLE 2

The directors of the American Dairy Science Association
(1933 to 1956, inclusive)

1933	*1934*	*1935*	*1936*
E. Weaver	E. Weaver	M. Mortensen	M. Mortensen
O. F. Hunziker	O. F. Hunziker	O. F. Hunziker	C. R. Gearhart
L. A. Rogers	L. A. Rogers	L. A. Rogers	L. A. Rogers
1937	*1938*	*1939*	*1940*
E. G. Hood	E. V. Ellington	J. W. Linn	C. N. Shepardson
E. Weaver	H. Macy	M. E. Parker	F. Ely
M. Mortensen	E. G. Hood	E. V. Ellington	J. W. Linn
J. A. Nelson	C. E. Wylie	H. Macy	M. E. Parker
C. R. Gearhart	C. R. Gearhart	E. G. Hood	E. V. Ellington
H. P. Davis	J. A. Nelson	C. E. Wylie	H. Macy
H. A. Ruehe	R. R. Graves	H. W. Gregory	E. Weaver
1941	*1942*	*1943*	*1944*
H. B. Ellenberger	G. M. Trout	R. B. Becker	C. L. Blackman
A. C. Dahlberg	J. C. Knott	W. E. Petersen	P. H. Tracy
C. N. Shepardson	H. B. Ellenberger	G. M. Trout	R. B. Becker
F. Ely	A. C. Dahlberg	J. C. Knott	W. E. Petersen
J. W. Linn	C. N. Shepardson	H. B. Ellenberger	G. M. Trout
M. E. Parker	F. Ely	C. R. Gearhart	J. C. Knott
E. S. Guthrie	H. W. Cave	H. F. Judkins	H. P. Davis
1945	*1946*	*1947*	*1948*
P. H. Downs	W. V. Price	C. Y. Cannon	J. H. Hilton
J. W. Linn	K. L. Turk	S. J. Brownell	P. F. Sharp
C. L. Blackman	J. W. Linn	W. V. Price	C. Y. Cannon
P. H. Tracy	P. A. Downs	K. L. Turk	S. J. Brownell
R. B. Becker	C. L. Blackman	J. W. Linn	W. V. Price
W.E. Petersen	P. H. Tracy	P. A. Downs	K. L. Turk
A. C. Dahlberg	A. C. Ragsdale	J. A. Nelson	F. Ely
1949	*1950*	*1951*	*1952*
P. R. Elliker	F. J. Arnold	J. H. Erb	I. A. Gould
H. B. Henderson	C. W. Turner	L. A. Moore	E. J. Perry
J. H. Hilton	P. R. Elliker	F. H. Arnold	J. H. Erb
P. F. Sharp	H. B. Henderson	C. W. Turner	L. A. Moore
C. Y. Cannon	J. H. Hilton	P. R. Elliker	F. J. Arnold
S. J. Brownell	P. F. Sharp	H. B. Henderson	C. W. Turner
P. H. Tracy	W. E. Petersen	G. M. Trout	R. B. Becker
1953	*1954*	*1955*	*1956*
N. N. Allen	D. V. Josephson	R. E. Hodgson	E. L. Fouts
L. H. Rich	G. W. Salisbury	G. Hyatt, Jr.	I. W. Rupel
I. A. Gould	N. N. Allen	D. V. Josephson	R. E. Hodgson
E. J. Perry	L. H. Rich	G. W. Salisbury	G. Hyatt, Jr.
J. H. Erb	I. A. Gould	N. N. Allen	D. V. Josephson
L. A. Moore	E. J. Perry	L. H. Rich	G. W. Salisbury
H. A. Bendixen	H. B. Henderson	W. V. Price	L. A. Moore

in a "Section on Problems and Methods of Instruction" at which six papers were presented. Another instruction section program was held at the 1937 meeting, in Lincoln, Neb., with 11 papers given.

Again, in 1955, the Executive Committee looked into the possibility of establishing an instruction section to be designated as the "Dairy Education Section." The president was instructed to appoint an education committee to consider the problems of establishing such a section and to recommend whether or not such a section should be established.

Advanced registry and official testing. A history of the American Dairy Science Association would not be complete without special treatment of Advanced Registry. Confronted with few records of the Association meetings from 1909 to 1917, the historian asked charter and early members what transpired at the first meetings of the Association. "What did you talk about?" was asked. "Advanced registry," was invariably the answer.

The height of discussions on testing and registry seemed to have been reached at the Chicago meeting in 1920, when a whole section was devoted to the subject. The report of the meeting comprised ten printed pages in the Journal.

TABLE 3

Section officers of the American Dairy Science Association

Year	Chairman	Vice-chairman	Secretary
	OFFICIAL TESTING AND ADVANCED REGISTRY SECTION		
1920-1921	H. P. Davis	———	M. H. Fohrman
1922	H. P. Davis	———	M. H. Fohrman
1923	H. P. Davis	L. H. Fairchild	R. T. Harris
1924	R. T. Harris	———	G. C. White
1925	R. T. Harris	———	G. C. White
1926	G. C. White	———	C. E. Wylie
1927	C. E. Wylie	———	W. E. Petersen
1928	P. S. Williams	———	J. M. Fuller
1929	A. C. Ragsdale	———	G. E. Taylor
1930	A. C. Ragsdale	———	G. E. Taylor
1931	E. L. Anthony	———	P. C. McGilliard
1932	E. L. Anthony	———	P. C. McGilliard
1933	(No officers listed; section discontinued)		
	PRODUCTION SECTION		
1920-1921	W. M. Regan	———	P. S. Williams
1922	W. M. Regan	A. C. Ragsdale	E. L. Anthony
1923	O. E. Reed	———	A. B. Rayburn
1924	J. J. Hooper	———	J. A. Gamble
1925	J. A. Gamble	———	J. P. LaMaster
1926	C. C. Hayden	———	O. G. Schaefer
1927	A. C. Ragsdale	———	H. W. Cave
1928	E. L. Anthony	———	C. F. Huffman
1929	F. Ely	———	R. B. Becker
1930	H. B. Ellenberger	———	C. W. Turner
1931	P. M. Brandt	———	W. B. Nevens
1932	G. Bohstedt	———	T. W. Gullickson
1933	J. H. Hilton	———	S. M. Salisbury
1934	H. O. Henderson	———	C. Y. Cannon
1935	C. Y. Cannon	———	R. H. Lush
1936	K. S. Morrow	———	W. E. Krauss
1937	F. W. Atkeson	W. E. Krauss	I. W. Rupel
1938	W. E. Krauss	H. W. Cave	I. R. Jones
1939	H. W. Cave	A. H. Kuhlman	A. L. Beam
1940	A. H. Kuhlman	W. E. Petersen	H. A. Herman
1941	W. E. Petersen	H. A. Herman	K. S. Morrow
1942	H. A. Herman	K. L. Turk	D. L. Espe
1943	K. L. Turk	D. L. Espe	G. W. Salisbury
1944	D. L. Espe	G. W. Salisbury	D. M. Seath
1945	G. W. Salisbury	D. M. Seath	G. Wise
1946	G. W. Salisbury	D. M. Seath	G. Wise
1947	D. M. Seath	G. Wise	L. A. Moore
1948	G. H. Wise	L. A. Moore	G. M. Cairns
1949	L. A. Moore	G. M. Cairns	L. O. Gilmore
1950	G. M. Cairns	L. O. Gilmore	N. N. Allen
1951	L. O. Gilmore	N. N. Allen	G. Hyatt, Jr.
1952	N. N. Allen	G. Hyatt, Jr.	P. L. Kelly
1953	G. Hyatt, Jr.	P. L. Kelly	R. E. Erb
1954	P. L. Kelly	R. E. Erb	N. P. Ralston
1955	R. E. Erb	N. P. Ralston	G. W. Trimberger
1956	N. P. Ralston	S. W. Mead	S. B. Marshall
	MANUFACTURING SECTION		
1920-1921	Roy Potts	W. P. B. Lockwood	A. W. Rudnick
1922	L. A. Rogers	C. L. Roadhouse	H. A. Ruehe
1923	H. A. Ruehe	———	J. R. Kiethley
1924	H. W. Gregory	———	R. C. Fisher
1925	H. F. Judkins	———	N. E. Olson
1926	A. C. Baer	———	C. D. Dahle
1927	E. S. Guthrie	———	W. H. E. Reid
1928	W. V. Price	———	P. S. Lucas
1929	W. H. Martin	———	J. C. Hening
1930	C. L. Roadhouse	———	C. D. Dahle

TABLE 3 (Concluded)
Section officers of the American Dairy Science Association

Year	Chairman	Vice-chairman	Secretary
	MANUFACTURING SECTION (Cont'd)		
1931	C. L. Roadhouse	————	A. O. Dahlberg
1932	R. B. Stoltz	————	E. G. Hood
1933	J. O. Barkman	————	P. H. Tracy
1934	H. Macy	————	J. H. Erb
1935	M. J. Mack	————	G. M. Trout
1936	L. M. Thurston	————	W. V. Price
1937	P. H. Tracy	————	J. C. Marquardt
1938	C. J. Babcock	————	B. E. Horrall
1939	P. A. Downs	F. H. Herzer	J. I. Keith
1940	F. H. Herzer	C. D. Dahle	S. T. Coulter
1941	C. D. Dahle	L. H. Burgwald	E. O. Anderson
1942	L. H. Burgwald	R. Whitaker	K. G. Weckel
1943	R. Whitaker	P. F. Sharp	R. J. Ramsey
1944	P. F. Sharp	L. K. Crowe	I. A. Gould
1945	L. K. Crowe	C. L.Hankinson	N. S. Golding
1946	L. K. Crowe	C. L.Hankinson	N. S. Golding
1947	C. L. Hankinson	P. R. Elliker	J. M. Trimble
1948	P. R. Elliker	E. M. Barker	D. V. Josephson
1949	E. M. Barker	D. V. Josephson	J. H. Hetrick
1950	D. V. Josephson	J. H. Hetrick	E. L. Jack
1951	J. H. Hetrick	E. L. Jack	O. F. Garrett
1952	E. L. Jack	O. F. Garrett	A. J. Morris
1953	O. F. Garrett	A. J. Morris	G. H. Hartman
1954	A. J. Morris	G. H. Hartman	W. M. Roberts
1955	G. H. Hartman	W. M. Roberts	H. L. Templeton
1956	W. M. Roberts	H. L. Templeton	F. J. Babel
	EXTENSION SECTION		
1921-1922	E. M. Harmon	C. A. Hutton	C. R. George
1923	E. M. Harmon	————	A. J. Cramer
1924	L. W. Morley	————	C. A. Hutton
1925	L. W. Morley	————	C. A. Hutton
1926	A. J. Cramer	————	C. R. Gearhart
1927	A. J. Cramer	————	C. R. Gearhart
1928	G. A. Williams	————	A. C. Baltzer
1929	G. A. Williams	————	A. C. Baltzer
1930	G. A. Williams	————	A. C. Baltzer
1931	M. J. Regan	G. E. Gordon	M. L. Black
1932	M. J. Regan	M. L. Black	C. R. Gearhart
1933	C. R. Gearhart	————	F. Johnston
1934	J. W. Linn	————	C. L. Blackman
1935	F. Johnston	————	C. L. Blackman
1936	E. J. Perry	————	E. N. Shultz
1937	C. L. Blackman	E. N. Shultz	S. J. Brownell
1938	E. N. Shultz	S. J. Brownell	R. G. Connelly
1939	S. J. Brownell	R. G. Connelly	O. J. Hill
1940	R. G. Connelly	O. J. Hill	G. W. Vergeront
1941	O. J. Hill	G. W. Vergeront	J. E. Kendrick
1942	G. W. Vergeront	J. F. Kendrick	E. C. Scheidenhelm
1943	J. F. Kendrick	E. C. Scheidenhelm	G. G. Gibson
1944	E. C. Sheidenhelm	F. Arnold	G. Heebink
1945	F. Arnold	W. T. Crandall	E. H. Loveland
1946	F. Arnold	W. T. Crandall	E. H. Loveland
1947	W. T. Crandall	E. H. Loveland	A. R. Porter
1948	E. H. Loveland	G. Heebink	C. W. Reaves
1949	G. Heebink	C. W. Reaves	R. Albrectsen
1950	C. W. Reaves	R. Albrectsen	R. D. Leighton
1951	R. Albrectsen	R. D. Leighton	I. E. Parkin
1952	R. D. Leighton	I. E. Parkin	S. N. Gaunt
1953	I. E. Parkin	S. N. Gaunt	E. T. Itschner
1954	S. N. Gaunt	E. T. Itschner	G. Werner
1955	E. T. Itschner	G. M. Werner	J. P. Burke
1956	G. M. Werner	J. D. Burke	L. R. Fryman

TABLE 4

The officers of the Eastern, Southern, and Western Divisions of the American Dairy Science Association

Year	Chairman	Vice-chairman	Secretary
		EASTERN	
1921-1922	R. C. Fisher	A. A. Borland	R. W. Smith, Jr.
1923	R. C. Fisher	A. A. Borland	R. W. Smith, Jr.
1924	R. C. Fisher	A. A. Borland	R. W. Smith, Jr.
1925	A. A. Borland	H. B. Ellenberger	R. W. Smith, Jr.
1926	H. B. Ellenberger	G. W. White	A. L. Beam
1927	J. M. Fuller	S. I. Bechdel	S. H. Harvey
1928	H. F. DePew	M. H. Campbell	M. J. Mack
1929	C. L. Allen	R. W. Smith, Jr.	M. J. Mack
1930	E. O. Anderson	C. D. Dahle	C. B. Bender
1931	A. L. Beam	P. F. Sharp	C. B. Bender
1932	E. S. Guthrie	C. B. Bender	R. E. Johnson
1933	C. B. Bender	F. J. Doan	R. E. Johnson
1934	R. W. Smith, Jr.	R. E. Johnson	H. G. Lindquist
1935	R. E. Johnson	M. J. Mack	H. G. Lindquist
1936	M. J. Mack	M. H. Campbell	J. A. Newlander
1937	A. R. Merrill	H. G. Lindquist	F. J. Doan
1938	H. G. Lindquist	M. H. Campbell	H. C. Moore
1939	M. H. Campbell	F. J. Doan	H. C. Moore
1940	F. J. Doan	K. S. Morrow	H. C. Moore
1941	K. S. Morrow	H. C. Moore	L. R. Dowd
1942	H. C. Moore	A. I. Mann	L. R. Dowd
1943	K. S. Morrow	H. C. Moore	L. R. Dowd
1944	K. S. Morrow	H. C. Moore	L. R. Dowd
1945	K. S. Morrow	H. C. Moore	L. R. Dowd
1946	K. S. Morrow	H. C. Moore	L. R. Dowd
1947	H. C. Moore	A. I. Mann	L. R. Dowd
1948	A. I. Mann	L. R. Dowd	J. A. Newlander
1949	L. R. Dowd	C. L. Norton	J. A. Newlander
1950	C. L. Norton	J. A. Newlander	J. O. Buchanan
1951	J. A. Newlander	F. I. Elliott	J. O. Buchanan
1952	F. I. Elliott	J. O. Buchanan	R. C. Foley
1953	J. O. Buchanan	R. C. Foley	Alec Bradfield
1954	J. O. Foley	Alec Bradfield	G. W. Trimberger
1955	Alec Bradfield	G. W. Trimberger	H. L. Wildasin
1956	G. W. Trimberger	H. L. Wildasin	N. E. Ward
		SOUTHERN	
1922-1923	C. W. Holdaway	C. W. Wylie	J. A. Gamble
1924	C. E. Wylie	J. P. LaMaster	J. A. Gamble
1925	J. P. LaMaster	C. A. Hutton	J. A. Gamble
1926	C. A. Hutton	———	J. A. Gamble
1927	J. S. Moore	———	J. P. LaMaster
1928	J. S. Moore	F. W. Fitch	A. C. Baer
1929	A. C. Baer	R. H. Ruffner	L. A. Higgins
1930	R. H. Ruffner	L. A. Higgins	J. S. Moore
1931	L. A. Higgins	E. Weaver	R. B. Becker
1932	E. Weaver	R. B. Becker	A. D. Burke
1933	R. B. Becker	A. D. Burke	R. H. Lush
1934	A. D. Burke	R. H. Lush	E. C. Elting
1935	R. H. Lush	E. C. Elting	A. H. Kuhlman
1936	E. C. Elting	A. H. Kuhlman	C. N. Shepardson
1937	A. H. Kuhlman	C. N. Shepardson	T. B. Harrison
1938	C. N. Shepardson	T. B. Harrison	C. G. Cushman
1939	T. B. Harrison	C. G. Cushman	R. E. Waters
1940	C. G. Cushman	R. E. Waters	C. D. Grinnells
1941	R. E. Waters	C. D. Grinnells	R. B. Becker
1942	C. D. Grinnells	R. B. Becker	J. P. LaMaster
1943	R. B. Becker	J. P. LaMaster	F. H. Herzer
1944	R. B. Becker	J. P. LaMaster	F. H. Herzer
1945	R. B. Becker	J. P. LaMaster	F. H. Herzer
1946	R. B. Becker	J. P. LaMaster	F. H. Herzer
1947	R. B. Becker	J. P. LaMaster	F. H. Herzer

TABLE 4 (Concluded)

The officers of the Eastern, Southern, and Western Divisions of the American Dairy Science Association

Year	Chairman	Vice-chairman	Secretary
		SOUTHERN (Cont'd)	
1948	J. P. LaMaster	F. H. Herzer	D. M. Seath
1949	F. H. Herzer	D. M. Seath	H. B. Henderson
1950	D. M. Seath	H. B. Henderson	P. M. Reaves
1951	H. B. Henderson	P. M. Reaves	W. M. Roberts
1952	P. M. Reaves	W. M. Roberts	Lynn Copeland
1953	W. M. Roberts	Lynn Copeland	S. P. Marshall
1954	Lynn Copeland	S. P. Marshall	W. A. King
1955	S. P. Marshall	W. A. King	H. C. Olson
1956	W. A. King	H. C. Olson	K. M. Autrey
1957	H. C. Olson	K. M. Autrey	J. W. Pou
		WESTERN	
1923-1924	W. M. Regan	A. H. Rishoi	R. C. Jones
1925	H. A. Bendixen	————	N. C. Jamison
1926	E. V. Ellington	————	N. C. Jamison
1927	F. W. Atkeson	————	N. C. Jamison
1928	G. D. Turnbow	————	J. C. Knott
1929	N. C. Jamison	————	J. C. Knott
1930	N. C. Jamison	————	J. C. Knott
1931	I. R. Jones	————	D. R. Theophilus
1932	D. R. Theophilus	————	R. W. Morse
1933	G. H. Wilster	————	R. W. Morse
1934	R. W. Morse	————	R. E. Hodgson
1935	J. A. Nelson	————	O. J. Hill
1936	J. A. Nelson	————	O. J. Hill
1937	O. J. Hill	J. Berry	D. L. Fourt
1938	A. J. Morris	H. Loughary	D. L. Fourt
1939	I. H. Loughary	G. A. Richardson	J. O. Tretsven
1940	G. A. Richardson	D. L. Fourt	J. O. Tretsven
1941	D. L. Fourt	N. S. Golding	H. P. Ewalt
1942	N. S. Golding	S. W. Mead	H. P. Ewalt
1943	N. S. Golding	S. W. Mead	H. P. Ewalt
1944-1946	(No meetings held; no officers elected.)		
1947	S. W. Mead	H. P. Ewalt	D. L. Fourt
1948	H. P. Ewalt	E. A. Jack	G. A. Richardson
1949	E. L. Jack	G. H. Wilster	R. E. Erb
1950	G. H. Wilster	I. H. Loughary	R. E. Erb
1951	I. H. Loughary	A. O. Shaw	E. A. Keyes
1952	A. E. Shaw	D. L. Fourt	E. A. Keyes
1953	D. L. Fourt	G. M. Drumm	L. R. Hunsaker
1954	G. M. Drumm	J. O. Young	L. R. Hunsaker
1955	J. O. Young	L. R. Hunsaker	I. W. Slater
1956	L. R. Hunsaker	I. H. Loughary	I. W. Slater

At the 1930 meeting in Ames, Iowa, the Production and Official Testing Sections held their programs jointly, and the following year the Official Testing Section was discontinued.

Divisions. The first major revised constitution of 1920 provided for the organization of divisions of the Association based upon geographical considerations. Consequently, the formation of an Eastern Division received favorable action at the 16th annual meeting, held at St. Paul in 1921. According to Article 8 of the revised constitution of 1922, the time and place of meeting for the divisions of the Association were to be fixed by the Executive Committee. Apparently the Southern Division was formed in 1922, for the second annual meeting was held in Memphis, Feb. 7, 1923. The Western Dairy Instructors Association was authorized in 1923 to form a Western Section of the American Dairy Science Association with W. M. Regan of California as president. The officers of these divisions are presented in Table 4.

Relationship of sections and divisions to the parent organization. In 1937, President R. R. Graves appointed a committee consisting of Earl Weaver, C. R. Gearhart, and J. A. Nelson to formulate procedure whereby any action taken by the sections should carry the official approval of the American Dairy Science Association before its release for publication. Accordingly, the committee drew up and presented at the 1938 meeting a specific set of directives, which was approved by the Executive Board. No subsequent actions of the Ex-

TABLE 5

Membership in the American Dairy Science Association by decades, 1906 to 1955, inclusive

The number of members and affiliates during the											
1st decade		2nd decade		3rd decade		4th decade			5th decade		
Year	No.	Year	No.	Year	No.	Year	No.		Year	No.	
							M[a]	*A*[b]		*M*	*A*
1906	17	1916	—	1926	327	1936	832	—	1946	1,583	182
1907	54	1917	144	1927	319	1937	928	30	1947	1,663	?
1908	69	1918	—	1928	—	1938	1,101	81	1948	1,747	?
1909	—	1919	—	1929	—	1939	1,465	156	1949	1,725	859
1910	76	1920	—	1930	—	1940	1,339	283	1950	1,703	750
1911	76	1921	201	1931	—	1941	1,321	391	1951	1,598	340
1912	120	1922	—	1932	240	1942	1,276	235	1952	1,554	264
1913	131	1923	—	1933	355	1943	1,324	108	1953	1,745	294
1914	—	1924	234	1934	596	1944	1,388	45	1954	1,784	362
1915	138	1925	261	1935	735	1945	1,407	32	1955	1,775	409

[a] M = Member.
[b] A = Affiliate (student).

ecutive Boards have rescinded or changed these rules. Briefly, the policy adopted, in general, is that no action taken by a section or division shall be purported to carry the Association approval until such approval has been granted by favorable action of the membership in annual meeting.

Membership in the American Dairy Science Association

The membership in the American Dairy Science Association has had a remarkable growth, far beyond the most fanciful dreams of its founders. Starting from 17 charter members in 1906, the Association has grown to over 2,000 members in 1956. This figure is exclusive of 468 affiliate members.

According to the constitution drawn up at the organizational meeting, membership in the Association was confined to instructors and investigators (of college rank) in the agricultural colleges, experiment stations, and dairy divisions of the United States and Canada. The early meetings seemed to be confined solely to these groups. In 1922 the Committee on Constitution and By-Laws, chairmanned by M. Mortensen, broadened the requirements for membership, which have prevailed to this time and which provide that any person with a professional background in dairying shall be eligible.

Upsurge in membership. After this clarification of membership eligibility the Membership Committee, headed by J. A. Gamble, canvassed the field in 1922 and found there were over

TABLE 6

Charter members of the "National Association of Dairy Instructors and Investigators," July 16, 1906

Name	Location at time of meeting	Present address
H. H. Dean*	Canada	———
J. W. Decker*	Ohio	———
C. F. Doane	Washington, D. C.	1510 N. 21st St., Salem, Oregon
C. H. Eckles*	Missouri	Wife's address: Ida's Grove, Iowa
W. J. Fraser*	Illinois	———
E. S. Guthrie	Ohio	Dairy Industry Department, Cornell University, Ithaca, New York
C. C. Hayden	Illinois	438 N. Buckeye St., Wooster, Ohio
H. A. Hopper*	Illinois	———
O. F. Hunziker	Indiana	103 Seventh Ave., LaGrange, Ill.
C. B. Lane*	Washington, D. C.	———
C. E. Lee	Illinois	2919 N. Prospect Ave., Milwaukee 11, Wisconsin
F. R. Rasmussen*	Iowa	Wife's address: Mrs. Faith E. Rasmussen, Admin. Asst., Ice Cream Merchandising Inst., Inc., Barr Building, Washington 6, D. C.
Charles Thom	Connecticut	207 Grant St., Port Jefferson, New York
J. M. Trueman*	Illinois	———
H. E. Van Norman*	Washington, D. C.	———
E. H. Webster*	Washington, D. C.	———
B. D. White*	Washington, D. C.	———

* Deceased

1,200 workers in the United States eligible for membership. Many were not as yet members. In 1930, 14 states and the District of Columbia had memberships of 10 or more each. New York, California, and Illinois led the list in total membership with 45, 38, and 32 members, respectively. Some 25 of the states had fewer than five members. C. L. Roadhouse and C. H. Eckles reported success in securing members from the commercial field.

By Dec. 31, 1947, membership totaled 1,663. Secretary Stoltz was certain there were at least 5,000 dairy scientists and commercial dairymen who would be members of the Association or subscribers to the Journal if they were familiar with this opportunity.

Robert Bear Stoltz' membership obsession. For the first 25 to 30 years in the life of the Association the membership growth was steady, but not phenomenal. Then, owing to the visionary obsession of one man, R. B. Stoltz, the Association's membership really "took off." He delegated membership responsibility to key men at the state level and his game of mapping membership gains by states was very effective in garnering members. The record by 5-year intervals shows 355, 1101, 1324, and 1747 members in 1933, 1938, 1943, and 1948, respectively. The year 1948 held the honors for peak enrollment until 1954 (Table 5).

Association dues. The membership dues of the American Dairy Science Association have increased 20-fold or 2,000% since the founding of the organization in 1906. Then, the annual dues were 50 cents, but it must be recalled that at that time the *Journal of Dairy Science* was not yet even a dream. Naturally, the founding of the Journal in 1917 materially increased the cost of the membership. Inflationary publication costs since World War II made necessary a marked increase in the annual dues. Prior to 1943, the dues were set by the constitution and by-laws. Since then they have been set by the Executive Board. Reluctantly, the Executive Board, in 1949, cast aside the $5.00 membership fee of 27 years' standing and set the fees at $6.00, effective Jan. 1, 1950. Since then, the Board has found it necessary to make two $2.00 increases in membership dues.

The following fees, by years, are of interest:

Year	*Dues*	*Benefits*
1906	$ 0.50	Membership only
1908	1.00	Membership only
1917	3.00	Membership and Journal
1920	3.00	Membership and Journal
1922	5.00	Membership and Journal
1925	5.00	Membership and Journal
1942	5.00	Membership and Journal
1950	6.00	Membership and Journal
1951	8.00	Membership and Journal
1955	10.00	Membership and Journal

Charter members. The charter members of the American Dairy Science Association deserve special recognition herein on the occasion of the 50th anniversary of the founding of the organization. Wilber J. Fraser, speaking on "The Formation of the American Dairy Science Association" at the 28th annual meeting, Urbana, Ill., 1933, said:

> "A total of 12 men from outside the state came, and these, with the five men then in this department, formed the association and became the charter members."

He then recited their names and whence they came. The names of these charter members are listed in Table 6.

Life and honorary life membership. Life and honorary life membership in the American Dairy Science Association is bestowed upon individuals by Executive Board action. Life membership is based largely on years of membership at retirement, whereas the honorary life membership carries the aura of meritorious service plus a minimum number of years of paid membership. Only one honorary life membership with citation is awarded annually, whereas the number of life memberships recognized yearly depends upon the number of qualified members entering retirement.

Student affiliates. Student affiliates or junior members have been a potent force in the growing strength of the Association. Junior chapters have been authorized at many of the schools. Although considerable emphasis has been placed on this element of membership during recent years, the idea of junior membership is not new. J. H. Frandsen spoke of this possibility at the 1924 meeting in Milwaukee. C. H. Eckles thought of organizing local groups of the Association. After much discussion a committee was appointed consisting of C. H. Eckles, chairman, J. H. Frandsen, and J. B. Fitch to formulate plans and make suggestions for creating junior membership.

Little more was heard about student affiliates or junior chapters of the Association until 1938, when J. A. Nelson reported on junior chapters to the Executive Board. A motion was adopted empowering the president to appoint a committee of three to formulate a plan of junior chapters of the American Dairy Science Association. President Gregory appointed J. A. Nelson, E. V. Ellington, and A. A. Borland.

Despite active committees, a marked, alarming decrease occurred in the membership of student affiliates during 1950. There was a loss of 410, bringing the membership down to 340. This decrease was attributed to two factors: *(a)* high dues; and *(b)* no tie-in of the student-affiliate program with the parent Association. Perhaps, also, the Korean War with its uncertainties and a decreasing dairy student body had some effect.

An active student affiliate committee, headed by Elmer N. Thomas, of the University of Minnesota, offered five suggestions at the 1951 meeting which they believed would greatly improve

the relationship of the Association with the students. On Dec. 31, 1953, there were 23 Student Affiliate Branches. During 1954, this number increased to 27, with 328 student affiliate members from 37 states, Canada, and Peru. The 1955 Student Affiliate Committee, with W. L. Slatter of Ohio as chairman, directed a highly acceptable student-activities display by 11 chapters at the East Lansing meeting.

Past experience indicated that potential leadership and Association membership existed in the dairy student body but that interest must be engendered by the educators themselves. The 1955 revised constitution and by-laws provide for formation of student branches as an integral part of the structure of the Association. The June, 1955, issue of the Journal carried a section called "Student Chapter News," and in December the announcement was made that this would be a regular feature starting in January, 1956, with E. L. Thomas of the University of Minnesota as editor.

Annual Summer Meetings

The annual summer meetings of the American Dairy Science Association have become a mecca for members and their families from widely scattered areas. Several of the events associated with annual summer meetings furnish a vital part of the history of the Association.

Selection of meeting sites. Selection of meeting places for the annual summer meetings has not always been easy. During the 29-year period since the East Lansing summer meeting of 1927

TABLE 7

Attendance at the annual meetings of the American Dairy Science Association, 1906 to 1955, inclusive

Meeting	Location	Year	Attendance				Representation	
			Men	Women	Children	Total	States[c]	Foreign countries[f]
1st	Urbana, Ill.	1906	18			18	7	1
2nd	Chicago, Ill.	1907	21			21	—	—
3rd	Ithaca, N. Y.	1908	47			47	18	2
		1909-1916	(No attendance record)				—	—
12th	Columbus, Ohio	1917	70			70	27	—
13th	Columbus, Ohio	1918	48	(flu epidemic)		48	—	—
		1919-1921	(No attendance record)				—	—
17th	St. Paul, Minn.	1922	300[a]			—	—	—
		1923-1926	(No attendance record)				—	—
22nd	East Lansing, Mich	1927	68	(in picture taken)		—	—	—
		1928-1929	(No attendance record)				—	—
25th	Ames, Iowa	1930	—			250[b]	—	—
26th	Berkeley-Davis, Calif.	1931	—			150[b]	—	—
27th	Lexington, Ky.	1932	200[b]	50[b]		280[b]	—	—
28th	Urbana, Ill.	1933				—	—	—
29th	Ithaca-Geneva, N. Y.	1934	250[b]	100[b]		350[b]	—	—
30th	St. Paul, Minn.	1935	325	121	33	479	37	2
31st	State College, Pa.	1936	355	134	144	603	35	2
32nd	Lincoln, Neb.	1937	303	76	32	411	40	6
33rd	Columbus, Ohio	1938	447	125	48	620	40	3
34th	Moscow-Pullman, Wash.	1939	196	113	81	390	34	2
35th	W. Lafayette, Ind.	1940	480	235[a]	—	715	—	—
36th	Burlington, Iowa	1941	492	352[a]	—	844	—	—
37th	East Lansing, Mich.	1942	394	93	79	566	39	1
38th	Columbia, Mo.	1943	—	—	—	318	34	1
39th	Columbus, Ohio	1944	—	—	—	384	38	1
40th	Chicago, Ill.	1945	(officers and two guests only)					
41st	Ames, Iowa	1946	532	225[c]	—	757	43	5
42nd	Guelph, Ontario	1947	583	328[c]	—	911	43	9
43rd	Athens, Ga.	1948	600	356[e]	—	956	44	1
44th	St. Paul, Minn.	1949	780	262	73	1,115	46	9
45th	Ithaca, N. Y.	1950	940	394	195	1,529	47	8
46th	Knoxville, Tenn.	1951	701	159	110	970	43	9
47th	Davis, Calif.	1952	371	167	102	640	43	6
48th	Madison, Wis.	1953	891	296	219	1,632[d]	46	13
49th	State College, Pa.	1954	875	321	232	1,428	46	6
50th	East Lansing, Mich.	1955	842	316	202	1,360	49	9

[a] Estimated attendance at banquet.
[b] Approximate number.
[c] Women and children.
[d] Including 100 guests and 126 affiliates.
[e] Including District of Columbia.
[f] Including Alaska and Hawaii.

various methods of locating a campus for the annual meeting have been followed. These involved *(a)* hopeful waiting for an invitation; *(b)* committee solicitation of likely schools for an invitation; *(c)* secretary invitation and decision; and *(d)* Executive Board choice of several invitations. At the Washington, D. C. meeting in 1929 it was believed that the meeting place should be decided and announced a year in advance so that members could plan their work and vacations.

Unbelievably, in the very midst of the "Depression," invitations for the 1933 meeting were received from six universities—Minnesota, Cornell, Pennsylvania, Purdue, Illinois, and Ohio. Sentiment was in favor of holding the 1933 meeting as close to Chicago as possible so that members en route "might attend the Chicago Century of Progress Exposition." Accordingly, after 27 years, the Association met again on the campus of the founding institution, the University of Illinois.

World War II brought special problems in the scheduling of meetings; nevertheless, meetings were arranged. On one occasion and at the last minute, even after the program was in print, the War Committee on Conventions denied the Association a permit to hold the 1945 meeting scheduled for Ames, Iowa. Consequently, the Executive Board met in the Stevens Hotel, Chicago, June 12 and 13, to conduct the necessary business matters, reserving Iowa's invitation for 1946.

Despite the action of the Executive Board in 1939 in placing an invitation for the 1942 meeting on file, and questioning the right of any board to set the place of an annual meeting this far in advance (3 years), the 1954 Executive Board projected the meeting sites as far ahead as 1961 (7 years). The 1955 Executive Board did even better; it accepted the University of Kentucky's invitation for 1965 (10 years). The Executive Board of 1950 recommended that a plan of rotation of annual meeting locations be instituted as a general guide for future meetings, whereby meetings may be held in the Midwest every other year (odd) and in the West, South, and East in rotation on the alternate years (even).

Attendance. The attendance at the annual meetings paralleled the rise in membership for a while and later increased more rapidly, owing in part to the introduction of women's and children's programs. Also, representatives from industry attended more frequently since greater attention was being given in the formulation of programs to research and less to instruction. Attendance data available are presented in Table 7.

Programs. The programs have ranged in type from selected speakers, open forums, committee reports, and research papers to symposia. Not all of the programs have been entirely satisfactory. As early as 1921 at the sixteenth annual meeting in St. Paul, Eckles said, "I am not entirely satisfied with the character of the programs we have been accustomed to have on these occasions." After detailed explanation he concluded:

> "Most other societies of a similar nature present a program either in the nature of scientific papers or addresses and reports by individual members. A common practice at scientific meetings is to have abstracts read of papers to be published in the journal of the society later. I believe this feature could be added to our program with advantage. I have no thought that it would be desirable to make the entire program of this character, but to add it as one feature. My suggestion is that the program should be a combination of (a) reports of standing committees, (b) papers or reports by individuals who have been asked to make reports on particular subjects, (c) abstracts of scientific papers by members—these to be limited to five or eight minutes each with the understanding that the full paper be submitted for publication in the Journal later. It would seem logical to place the responsibility for the programs of the sections upon the officials of the sections, leaving the general officers the responsibility for the general program."

By the end of the 25th annual meeting at Ames in 1930, rumblings began to be heard again concerning the quality of the programs. This might have been foreseen since attendance at the meetings had increased considerably and at least three sections of programs were running concurrently. The programs tended to shift to numerous progress reports rather than finished papers. These encroached upon time for discussion. The Proceedings for the 1930 meeting record, in part:

> "The program was a full one. The diversity of interests and activities of the dairy industry result in programs run more or less like a three-ring circus.
>
> "There is an angle to these programs that seems somewhat unfortunate. You hear a paper read in which you are interested, one that you would like to go over carefully and digest thoroughly. But unlike the proceedings of some scientific societies, it has been the practice of the American Dairy Science Association not to publish the papers presented. Some of the reasons for this are: that many of the papers are merely a report of progress of investigations that will be published later in more detail; that some people do not want a paper published that will have to be briefed to the extent necessary for presentation in the time allowed on the program; then too, publication would perhaps mean the necessity of a review of the papers by the Program Committee prior to the meeting."

Printed abstracts of papers presented at the annual meetings helped alleviate any dissatisfaction over the programs. These were first made available to registering members in 1931. This introduction was so successfully followed at the 1932 meeting that the procedure has continued since, with some exceptions.

The programs continued to improve in subject-matter coverage and in diversity of presentation. Those of the post-World War II period will go down in history as being unequaled by those of any other scientific agricultural society.

Achievement Awards

Late in the 1930's the first of a number of achievement awards was made available to the American Dairy Science Association by The Borden Company Foundation, Inc. Immediately acclaimed by the members as a means of rendering due recognition to its renowned members—a recognition which the Association itself could not render because of the lack of sufficient funds—there yet remained some belief that soon the supply of potential worthy awardees would be exhausted. Nineteen years has proven the fallacy of this thinking. These and other awards have stimulated activity in the various fields, and the announcement of the winners has become an anticipated high light of the annual meeting (Table 8).

1. *The Borden Awards.* The Borden Awards for meritorious research both in dairy manufacturing and in dairy production consist of a citation by the American Dairy Science Association and a gold medal and a tax-free check for $1,000 by the Borden Company Foundation. With few exceptions, the 38 dairy Borden Awards from 1937 to 1955, inclusive, have been made by Mr. W. A. Wentworth of the Borden Company.

TABLE 8

Achievement and honor awards presented at the annual meeting of the American Dairy Science Association

Year	Recipients	
	THE BORDEN AWARDS	
	DAIRY MANUFACTURING	DAIRY PRODUCTION
1937	Lore A. Rogers, USDA	Carl F. Huffman, Michigan
1938	Kenneth G. Weckel, Wisconsin	William E. Krauss, Ohio
1939	Stewart L. Tuckey, Illinois	Ralph E. Hodgson, USDA
1940	Bernard W. Hammer, Iowa	Charles W. Turner, Missouri
1941	Paul F. Sharp, Cornell	Edwin B. Hart, Wisconsin
1942	Hugo H. Sommer, Wisconsin	William E. Petersen, Minnesota
1943	Byron H. Webb, USDA	Lane A. Moore, USDA
1944	Arthur C. Dahlberg, Cornell	Paul H. Philips, Wisconsin
1945	G. Malcolm Trout, Michigan	Glenn W. Salisbury, Cornell
1946	Paul H. Tracy, Illinois	E. Paul Reineke, Michigan
1947	Chester D. Dahle, Pennsylvania	Joseph C. Shaw, Maryland
1948	Egerton G. Hood, Canada	Walter L. Gaines, Illinois
1949	Francis J. Doan, Pennsylvania	George H. Wise, North Carolina
1950	Walter V. Price, Wisconsin	Samuel Brody, Missouri
1951	Samuel T. Coulter, Minnesota	John K. Loosli, Cornell
1952	Emerson W. Bird, Iowa	John Wm. Hibbs, Ohio
1953	F. E. Nelson, Iowa	R. B. Becker, Florida
1954	Paul R. Elliker, Oregon	L. E. Casida, Wisconsin
1955	Frank V. Kosikowski, Cornell	Clifford W. Duncan, Michigan
	THE AMERICAN FEED MANUFACTURERS ASSOCIATION AWARD	
1948	George H. Wise, North Carolina	
1949	Thomas S. Sutton, Ohio	
1950	J. Thomas Reid, Cornell	
1951	Thor. W. Gullickson, Minnesota	
1952	Hamilton E. Eaton, Connecticut	
1953	J. W. Thomas, United States Department of Agriculture	
1954	Carl F. Huffman, Michigan	
1955	Robert S. Allen and Norman L. Jacobson, Iowa (joint awards)	
	THE DE LAVAL DAIRY EXTENSION AWARD	
1951	Enos J. Perry, Rutgers	
1952	Stanley J. Brownell, Cornell	
1953	G. E. Gordon, California	
1954	C. R. Gearhart, Pennsylvania	
1955	Floyd J. Arnold, Iowa	
	THE AMERICAN DAIRY SCIENCE ASSOCIATION TEACHING AWARD	
1955	Frederick H. Herzer, Mississippi	

2. *The American Feed Manufacturers Association Award.* This award, inaugurated in 1948, is based on the publications during the two preceding years, the research being evaluated on *(a)* originality; *(b)* presentation; *(c)* value in dairy cattle nutrition; and *(d)* possibility of practical use in the dairy cattle industry. The recipient receives a check for $1,000 and a plaque.

3. *The DeLaval Dairy Extension Award.* The DeLaval Dairy Extension Achievement Award of $1,000 and a scroll were given for the first time in 1951. It is sponsored by the DeLaval Separator Company as a living memorial in honor of Dr. Carl Gustaf Patrick DeLaval, inventor of the centrifugal cream separator and one of the chosen "Ten Masterminds of Dairying."

4. *The American Dairy Science Association Teaching Award.* The Teaching Award in Dairy Manufacturing, first given in 1955, was sponsored by the Milk Industry Foundation. The Dairy Production Teaching Award, presented in 1956, was donated by the National Dairy Products Corporation. Like the other awards, the cash value is $1,000. The Manufacturing and Production Teaching Awards will be made in alternate years by the Foundation and by National Dairy.

Distinctive Membership Recognition

1. *The Association honorary member award.* At the 1932 meeting, J. B. Fitch and Elmer Wylie spoke in favor of honoring at the annual meeting members who had rendered distinctive service to the dairy industry. At the 1934 meeting J. M. Sherman presented the following motion, which was adopted after much discussion: that a permanent committee be appointed to pass on honors conferred on individuals at annual meetings; that this be a standing committee consisting of the last three presidents and that the committee make its report to the Board of Directors.

In June, 1945, the Executive Board at the annual meeting approved the recommendations of the Committee on Honors or Special Recognition, which provided for an annual Association Honorary Member Award. Prior to this action the Association had considered favorably the suggestion made by Fitch and Wylie and had paid "honorary tribute" to four of its members. Those so honored were: 1933, Wilber J. Fraser; 1934, Otto F. Hunziker; 1935, Martin Mortensen; and 1940, Julius H. Frandsen.

Also, four charter members of the Association had been elected previously to honorary life membership by the Executive Board. These were: in 1942, O. F. Hunziker and in 1944, W. J. Fraser, E. S. Guthrie, and C. C. Hayden.

The Committee on Honors, consisting of A. C. Dahlberg, H. P. Davis, and H. F. Judkins, chairman, recommended that the Association honoree shall have been a member of the Association for at least 10 years and have rendered meritorious service. No more than one Honorary Member Award may be conferred during any one year. The honorary member is awarded the Association's Certificate of Honorary Membership and full membership in the Association, including a subscription to the *Journal of Dairy Science,* during his lifetime without the payment of further dues. The interest manifested at awarding ceremonies bespeaks the wisdom of the Committee in providing for this honor. Those so honored to date are:

1946, O. E. Reed	1951, L. A. Rogers
1947, R. B. Stoltz	1952, C. L. Roadhouse
1948, A. A. Borland	1953, H. P. Davis
1949, H. B. Ellenberger	1954, J. B. Fitch
1950, M. J. Prucha	1955, W. A. Wentworth

2. *The Association life membership.* The Association gives life membership to those who have been members for at least 25 years at the time of their retirement from active duty. On the occasion, the Association's Life Membership Certificate is presented to the life member. Life members receive the *Journal of Dairy Science* gratis as long as they live. The list of life members has included:

1944, E. G. Hastings	1948, Robert S. Breed
Chris Larsen	1952, C. Albert Altwegg
L. A. Rogers	1953, C. W. Holdaway
1945, Oscar Erf	1955, H. E. Otting
George C. White	
1947, S. I. Bechdel	
H. A. Harding	
C. W. Larson	
H. E. Ross	

3. *Charter honorary membership.* By interim action of the Executive Board, in 1956, a special charter honorary membership was bestowed upon the charter members of the Association who had not been so honored heretofore. These memberships carry all the rights and privileges of the regular Honorary Membership and have been awarded in order to pay extra tribute to those men for their contributions to the early life of the Association. Charter honorary memberships were bestowed upon C. F. Doane, Carl E. Lee, and Charles Thom.

Some Accomplishments of the American Dairy Science Association

Education of dairy scientists and industry leaders. The training of dairy scientists has made marked progress during the life of the Association. It must be recalled that at the turn of the century trained dairy educators were few. The Bachelor's degree itself was a mark of distinction. Its possessor was trained broadly in the sciences as well as in the fundamentals of dairy science. By 1920, the Master's degree was being earned by several of the college dairy instructors and investigators.

Eckles, in his presidential address in 1922, warned:

> "We are not turning out enough thoroughly prepared men. There should be more graduate students in dairy husbandry than is the case at present. The time is already here when a man to fill a first-class college position and rank with other men with whom he is associated must have a good graduate course. . . . I feel it is even more to the credit of the institution and more service to the state to turn out a few thoroughly qualified men who become leaders in their lines than it is to overemphasize the importance of turning out a graduate who can immediately turn his hand to practical work but whose training has been inadequate to enable him to do real constructive work of permanent value."

Within 10 years of Eckles' warning, members of dairy staffs throughout the country were seeking further training in graduate studies leading to the terminal degree. By mid-century, colleges of agriculture were demanding men with the doctorate to fill positions on their research and teaching staffs. As a consequence, both dairy curricula and instruction were placed on a higher level. The dairy graduate of 1956 is far more adequately trained in the fundamentals of dairy science than was his predecessor of 1906.

Committee studies and recommendations. The American Dairy Science Association has functioned chiefly through its committees. Since the founding of the society in 1906, the work of the committees has given strength to the Association. Largely through committees' study have come recommendations for administrative action, policies, procedures, and standards which carry the support and backing of the Association.

In the organizational meeting seven three-member committees were appointed. Apparently, the 21 team members were workers, for two years later extensive reports were given at the annual meeting. The conclusive reports of these committees set a pattern for accomplishment that has seldom been equaled. For example, Fraser, Eckles, and Dean's committee recommendations on experimental work in production served as a guide in this phase of research for many years.

By 1917, the committees not only grew in number, from 7 to 19, but increased in membership per committee as well, 93 persons being listed, some of whom served on more than one committee. In 1918, O. E. Reed remarked that there were too many inactive committees—a problem which has plagued officers to this day. There was general agreement, but it was pointed out that committee work was a means of getting the younger men interested and working for the Association. Although the number of committees remained the same, their membership had increased to 105 in 1919. In 1955, the number was 50 with a total personnel of 204, many of whom were younger men.

Committee reports continued to be a part of the annual programs, but in time the trend was toward progress reports rather than exhaustive, conclusive results. Nevertheless, the long list of accepted procedures, standards, and values in the realms of the dairy industry today attest the fact that the American Dairy Science Association's committees have functioned well.

Obviously, it is beyond the scope of this history to report the findings of all the committees. The mere mention of the names of some of the committees, past or present, immediately calls to mind some of the accomplishments of the Association. Some policy and subject-matter committees may be listed: advanced registry and official testing, breeds relation, score cards, Babcock testing, soft curd, curriculum, public relations, inter-society, composite tests, dairy cattle judging, milk proteins, dairy cattle breeding, teaching methods, judging dairy products, dairy records, dairy cattle health, pasture-investigation technique, type classification, standardization of methods, by-products, pasture and roughage, 4-H dairy clubs, dairy farm management, sanitary procedure, oxidation, color, dairy products, feeding, sires, chemical methods for analysis, bacteriological methods, and cost of milk production.

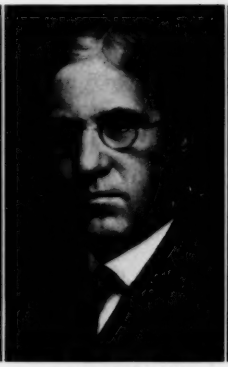
Six long-standing committees have had a significant influence on the dairy industry, its personnel and its Association. These are *(a)* advanced registry and official testing; *(b)* breeds relations; *(c)* judging dairy cattle; *(d)* judging dairy products; *(e)* journal management, and *(f)* curriculum.

Cooperation with other organizations. As previously indicated, the American Dairy Science Association early began close association with the National Dairy Show. The Manufacturing Section, through the Committee on Judging Dairy Products, has worked in close alliance with the Dairy Industries Supply Association continuously since 1930 in staging the Collegiate Students International Contest in the Judging of Dairy Products held in connection with the Dairy Industries Exposition.

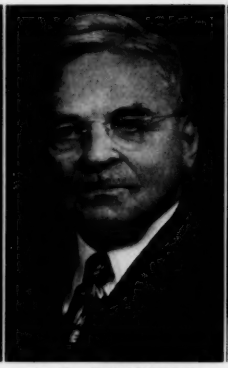
As science progressed and more scientific societies came into being, the American Dairy Science Association became affiliated with them. As early as 1923, the A.D.S.A. had representation on the National Research Council. Today major affiliations which involve formal representation by the Association are: American Association for the Advancement of Science, Committee on Inter-Society Cooperation, Dairy Remembrance Fund, Dairywide Coordinating Committee on Nutrition Research, Joint Committee on Grassland Farming, National Research Council, and Ralston-Purina Research Fellowship Committee.

PRESIDENTS OF THE AMERICAN DAIRY SCIENCE ASSOCIATION

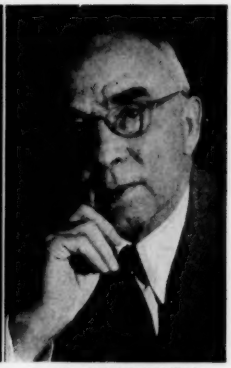
R. A. PEARSON
1st President
1906, 1907



C. H. ECKLES
2nd President
1908, 1909



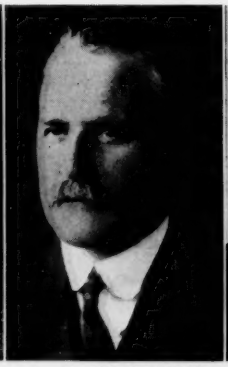
O. F. HUNZIKER
3rd President
1910, 1911



J. H. FRANDSEN
4th President
1912, 1913
Founder and first editor
Journal of Dairy Science

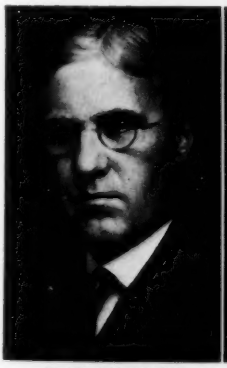
F. RASMUSSEN
5th President
1914, 1915

W. A. STOCKING
6th President
1916, 1917, 1918



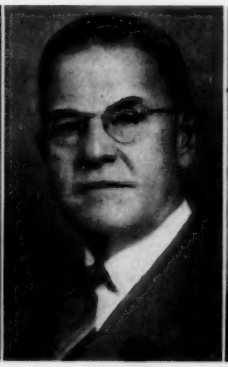
A. C. ANDERSON
7th President
1919

M. MORTENSEN
8th President
1920

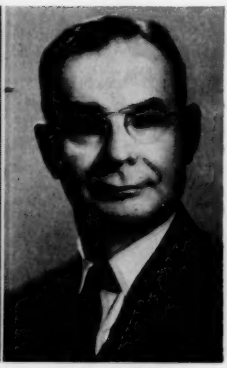


C. H. ECKLES
9th President
1921, 1922

A. A. BORLAND
10th President
1923, 1924

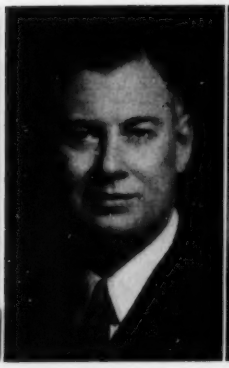


O. E. REED
11th President
1925, 1926



J. B. FITCH
12th President
1927

G. C. WHITE
13th President
1928, 1929



J. M. SHERMAN
14th President
1930

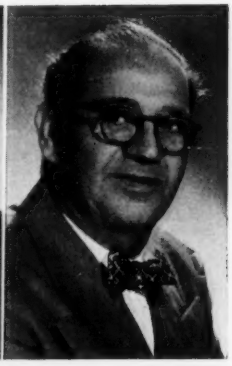
H. B. ELLENBERGER
15th President
1931

E. L. ANTHONY
16th president
1932

H. C. JACKSON
17th President
1933

R. B. STOLTZ
18th President
1934

C. L. ROADHOUSE
19th President
1935



H. A. RUEHE
20th President
1936

R. R. GRAVES
21st President
1937

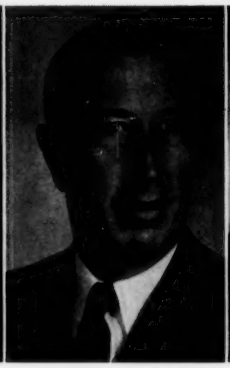
H. W. GREGORY
22nd President
1938

EARL WEAVER
23rd President
1939

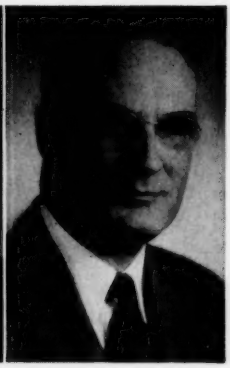
E. S. GUTHRIE
24th President
1940

H. W. CAVE
25th President
1941

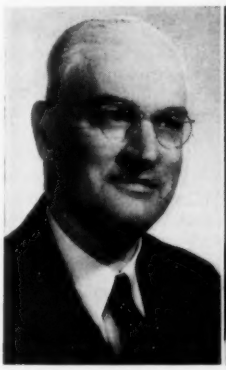
H. F. JUDKINS
26th President
1942



H. P. DAVIS
27th President
1943

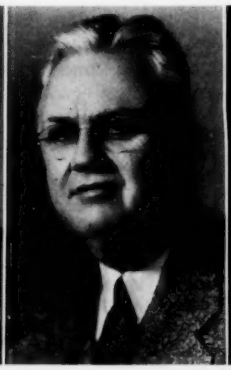


A. C. DAHLBERG
28th President
1944



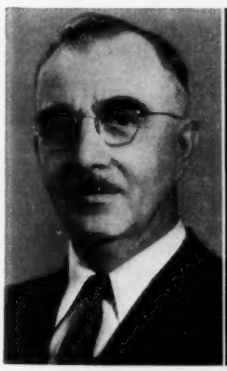
A. C. RAGSDALE
29th President
1945

J. A. NELSON
30th President
1946



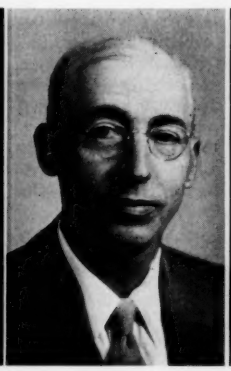
FORDYCE ELY
31st President
1947

P. H. TRACY
32nd President
1948

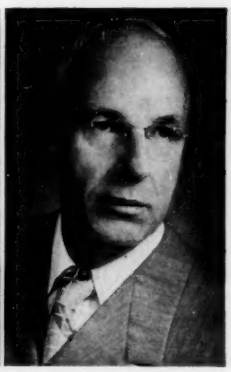


W. E. PETERSEN
33rd President
1949

G. M. TROUT
34th President
1950



R. B. BECKER
35th President
1951

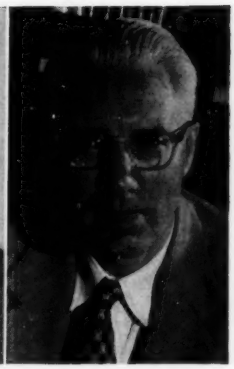


H. A. BENDIXEN
36th President
1952

H. B. HENDERSON
37th President
1953

W. V. PRICE
38th President
1954

L. A. MOORE
39th President
1955

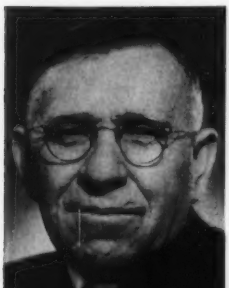


I. A. GOULD
40th President
1956

In Retrospect

W. J. Fraser, recounting in 1933 the events which led to the formation of the American Dairy Science Association, concluded "The spirit of inquiry . . . should always be the guiding spirit of our association."

This spirit of inquiry grew out of the very first meeting and has prevailed through the 50 years of the Association. It is one of the Association's chief values, for out of it have come most of the discoveries of the dairy scientists. In the dairy industry, as elsewhere, "Nature has always been a guardian of her secrets; they have been wrested only by long, laborious, tedious processes." Substantial, valuable research data might have been obtained, but it was the inquiring mind that drove the research worker on until he could answer the ever-present question, "Why?"



C. F. HUFFMAN
41st President
1957

Finally, it must be admitted and recorded that the influence of the American Dairy Science Association can be measured only by the lives it has touched. And these are immeasurable. Radiating out from distinguished men, such as gather at the annual meetings, are forces destined to leave their imprint on the minds of those within their range. Only by evaluating a life of active service may these influences be viewed in proper perspective.

Just as one working his way through the woods realizes that some trees are bigger than others, one unraveling the 50-year history of the American Dairy Science Association senses variations in the leadership stature of men. Some men have "stood tall" in depth of thought, loyalty, sincerity, and selflessness.

The Historian yearns to point out and characterize the "Ten Masterminds of the American Dairy Science Association." Yet, mindful of the Norwegian axiom, "No names mentioned, no one forgotten," he leaves the naming to the reader. Perhaps, some older member will rightfully include himself in the group of those contributing most to the American Dairy Science Association, and too, maybe some younger member, contemplating the leadership of the past, will dream dreams of a greater dairy industry and, working toward that goal, will have "forgotten" himself into celebrity.

Such has been the challenge of the American Dairy Science Association. Its records contain a rich heritage of dairy leaders and their accomplishments.

ACKNOWLEDGMENT

The author feels a special debt of gratitude to E. L. Anthony, A. C. Dahlberg, J. H. Erb, C. W. Duncan, I. A. Gould, and Earl Weaver for their helpful suggestions in the preparation of this manuscript.

Progress in the Basic Chemistry of Milk[1]

ROBERT JENNESS

Department of Agricultural Biochemistry, University of Minnesota, St. Paul

Much of the progress made in the last half-century in the basic knowledge of the chemistry of milk has consisted of filling in details in a picture whose broad outlines were already delineated. Thus in 1906 considerable information was available on the gross chemical composition of milk and on variations therein. The over-all composition and properties of the major constituents were known, a considerable list of "minor" constituents had been compiled, and several physical properties of milk had been measured rather accurately. Some progress had been made in understanding such basic dairy processes as churning and rennin coagulation. This appraisal can be verified by a glance at such texts as the first or second editions of Richmond's *Dairy Chemistry*, published in 1899 and 1914, respectively. Although they are obviously inadequate for a modern treatment of the subject, they present an over-all outline that is still essentially correct.

Robert Jenness

Researches conducted in various fields with diverse points of view and objectives, such as milk secretion, dairy manufacturing, and nutrition, have contributed to the present pool of knowledge of the chemistry of milk. Furthermore, some of the most notable advances have been made by chemists and biochemists who were not primarily interested in dairy problems at all but who were studying a particular class of compounds or reactions that happens to be represented in milk. For example, the chemistry of milk fat was investigated by Hilditch and that of lactose by Haworth, who were interested in the general fields of fats and sugars, respectively.

The chemistry of milk is an applied phase of the discipline of biochemistry. Milk contains representatives of most of the classes of biochemical materials and manifests the physical phenomena associated with them. Thus, in a sense, milk chemistry is as broad as biochemistry and most phases of the latter can contribute to it. Naturally, advances in our understanding of milk have occurred only as rapidly as the advance of basic biochemical knowledge and methodology.

Progress has been sporadic as techniques have become available and interests have shifted from one phase of dairy chemistry to another. Activity in the entire field has gradually increased, as is attested by the increase in number of research papers appearing per year.

Discovery of New Chemical Constituents

The list of chemical constituents of milk has grown somewhat since 1906, partly by the discovery of new ones and partly by fractionation of previously recognized groups. The principal group of new milk constituents discovered since 1906 is the vitamins. Actually, milk itself was used in some of the earliest demonstrations of these "accessory growth factors" by Hopkins in experiments dating from the very year 1906. At least one of these substances, riboflavin, had been recognized previously as being present in milk (under the name "lactochrome"), but its nutritional significance had not been suspected. All of the recognized vitamins have been detected in milk by isolation or by specific chemical or biological tests. All are present in appreciable amounts except vitamin K, which occurs only in traces. Aside from their importance in nutrition some of the vitamins, such as ascorbic acid and riboflavin, are important participants in chemical reactions in milk.

Other than the vitamins, the list of new constituents includes a variety of materials. Free glucose has been found in concentrations of about 50 mg. per liter, and small quantities of several other sugars and of a number of sugar phosphates also have been identified. Urea and ammonia were recognized before 1906 as contributors to the nonprotein nitrogen of milk. Several other materials have since been identified in that category, including orotic acid (detected in 1904, structure established in 1930), uric acid, adenine, guanine, creatine, creatinine, hippuric acid, various free amino acids, and indican. Two phosphatases (acid and alkaline) and aldolase have been added to the list of milk enzymes. The sum total of constituents discovered since 1906 constitutes only a small percentage of milk, but they are materials that cannot be neglected in consideration of the nutritive value and chemical reactions of milk.

Composition and Properties of Major Milk Constituents

The constituents of milk that could be listed in 1906 have been resolved and characterized with the result that they are much more completely known now than then. Perhaps the most spectacular examples of such resolution are the milk proteins, which were considered in 1906, and indeed long thereafter, to consist of three entities—casein, lactalbumin, and lactoglobulin. Each of these fractions eventually was shown

[1] Paper No. 922, Miscellaneous Journal Series, Minnesota Agricultural Experiment Station.

to be heterogeneous. This was first revealed for casein by preparation of fractions differing in composition and properties by various workers, including Osborne and Wakeman in 1918 and Linderstrom-Lang in 1925-29. The crystallization by Palmer in 1934 of a portion of lactalbumin as a protein (β-lactoglobulin) having different properties from the parent substance destroyed the idea that lactalbumin was homogeneous. The past 20 years has been a period of great activity and advance in protein chemistry. Modern techniques of electrophoresis, measurement of particle size, and amino acid analyses have enabled complete characterization of some proteins. Application of these techniques to milk revealed the presence of three components in casein and at least eight in the proteins of whey *(14)*. Warner, McMeekin, and coworkers at the Eastern Regional Laboratory of the U. S. Department of Agriculture succeeded in separating and purifying the three caseins (α, β, and γ) *(14)*. The same group also was the first to crystallize two of the whey proteins (α-lactalbumin and "blood" serum albumin). Two "immune" globulins carrying the antibodies of milk were isolated in relatively pure state and characterized by Smith in the 1940's *(19)*. The principal milk proteins have been rather thoroughly characterized as regards amino acid composition and physical properties.

The milk enzymes were more or less scientific curiosities in 1906. Some of them have remained in that category, although others have been studied intensively in relation to dairy problems. Thus the utility of alkaline phosphatase and peroxidase as indicators of heat treatment furnished the impetus for much chemical study. The lipases of milk have received considerable attention in connection with problems of rancidity. Two milk enzymes, peroxidase and xanthine oxidase, have been crystallized.

The general features of the composition of milk fat were known in 1906 and a reasonably accurate analysis of its principal fatty acids had been made by Browne in 1899. Improvements in fractionating techniques have provided even more accurate analyses, and variations in composition, particularly as influenced by feed, have been defined. Furthermore, painstaking analyses by Hilditch at the University of Liverpool, Brown at Ohio State University, and Shorland in New Zealand have revealed the presence of small amounts of a considerable number of additional fatty acids, including C_{10}-C_{16} monounsaturated, C_{18} polyunsaturated, C_{20}-C_{26} saturated and unsaturated, branched chain and uneven carbon number acids (see review by Jack and Smith, *7)*. From the standpoint of number of different fatty acids, milk fat is one of the most complex of natural fats. Since it contains about a dozen major acids and a large number of "minor" ones and appears to consist of mixed triglycerides, it is not surprising that little progress has been made in elucidating its structure in terms of specific triglyceride components.

The physical structure and properties of milk fat are of great importance in the dairy industry. In particular, the melting and crystallization phenomena are of interest. Considerable study has been made of these properties of fat in bulk, and a little progress has been made with calorimetric and dilatometric methods in defining physical changes of fat in the form of globules in dairy products.

Lactose, long recognized as the specific sugar of milk, had been shown by Emil Fischer before the turn of the century to be a disaccharide of glucose and galactose. Its correct structure was determined by Haworth and Long in 1927, and it was finally synthesized by straightforward organic chemistry by Haskins, Hann, and Hudson in 1942. Some interesting and important problems in dairy products (sandiness in ice cream, caking dry milk, crystallization in concentrated milk) center about the solubility and crystallization of lactose. The basic physical chemistry of these processes in simple solution and in various dairy products was worked out in the late twenties and early thirties largely by Sharp and Herrington and their coworkers at Cornell University (see review by Whittier, *20)*.

Variations in Milk Composition

Milk, even from a single species, varies greatly in composition. Its nutritive and economic value, and in some cases its physical and flavor stability, depends on its composition. Thus it is natural that a great deal of study of milk composition should have been made in the past 50 years and that a vast amount of data has accumulated. The ranges of variation of most of the constituents of cow's milk have been rather completely defined, and considerable progress has been made in assigning the variation to various genetic, physiological and environmental factors. Inter- and intra-breed variations, season, feed, and udder infection have received a large share of attention. The fat content has been studied most thoroughly because of its overwhelming economic importance, but variations in the solids-not-fat constituents have also been determined in some instances.

In the period 1913 to 1919 Eckles, Shaw, and Palmer at the University of Missouri published an important series of reports demonstrating the influence of such factors as plane of nutrition, age of cow, breed, individuality, stage of lactation, gestation, and parturition on the composition of milk. Tocher in 1925 presented a thorough evaluation of the over-all variation in composition of milk produced in Scotland during a period of 14 months. In the late twenties and thirties Overman and coworkers at the University of Illinois made a painstaking study of milk composition and particularly of inter-breed differences. Golding and coworkers at the National Institute for Research in Dairying in England analyzed variations in composition of

milk within a single herd over a period of several years in the thirties, and many subsequent studies of milk have been made at that institution. Herman and Cobble of the University of Missouri have recently published results of controlled experiments defining the effects of environmental temperature on the composition of milk.

No complete and critical compilation of the mass of data available on milk composition has ever been made, although in a publication of the National Research Council *(13)* Macy and coworkers have compiled ranges and average values for most of the constituents.

The relation between fat and solids-not-fat has been found to vary considerably and to depend on breed, feed, and udder infection. These factors have been held responsible for the decline of solids-not-fat content of milk produced in England in the period 1900-1950 (see review by Davis, *3)*.

Physical Chemistry of the Milk System

The chemistry of milk was treated in 1906 largely from the organic and analytical standpoints. Little attention was given to the physical equilibria involved. The emphasis has shifted gradually and a great deal of progress has been made in our understanding of these physical equilibria, but much remains to be learned. One outstanding advance during the half century has been the application of the concepts of pH and buffer action to milk and milk products. Problems of acid-base equilibria are of tremendous importance in dairy chemistry; they could not be dealt with intelligibly until the use of pH was introduced by Sorensen in 1909. The advent of the glass electrode, which came into general use in the thirties, made pH determinations so routine that it is now difficult to imagine attempting research without them. The acid-base equilibria of milk were described by Clark *(2)* and others and shown to be rather complex because of the participation of a number of buffer acids, phosphate, citrate, and bicarbonate, which form complexes with the divalent cations, calcium and magnesium. As a matter of fact the equilibria among the various salts and ions in milk have proved difficult problems and still are far from being completely defined.

Such workers as Palmer *(15)* and Porcher *(17)* in the twenties championed the view that milk is a complex colloidal system containing matter in various states of dispersion—solution, emulsion, and colloidal—and that many of the problems of dairy chemistry must be considered within the framework of these physical equilibria. Elaborating on the technique of "cream-washing" described by Storch in 1896, Palmer and his coworkers showed that the so-called fat-globule "membrane" adsorbed on the surface of the fat globules of milk is a phospholipide-protein complex. This material largely determines the behavior and properties of the fat globules and must be reckoned with in many dairy processes (see review by King, *11)*.

Many microscopic studies have been made of the size distribution of the milk fat globules and of the effects of various treatments, particularly homogenization, on them. Microscopy has proved most useful, especially in the hands of King, in following changes in the physical state of the fat in dairy processing and products.

The nature and structure of the colloidal caseinate particles have been investigated by numerous workers *(18)*. It seems to be established that they consist of a complex of the caseins, calcium, and phosphate. Centrifugal sedimentation and electron microscopy have revealed them to be roughly spherical and of the order of 30-300 $m\mu$ in diameter. Their fine structure and the nature of the forces joining their components have not been defined precisely. During the half-century the weight of opinion has fluctuated between the concepts of a double calcium salt of casein and phosphate and an association of separate caseinate and calcium phosphate particles. Neither point of view has been proved rigorously.

The physical properties of milk have been studied rather thoroughly since 1906. The classic work of Monier-Williams in 1914 and Hortvet in 1921 made freezing point the method of choice to detect added water. Subsequently many data have been compiled on the extent of variation in the freezing point of normal milk. Similarly, specific gravity determinations (particularly by lactometers) have been used a great deal in attempts to calculate total solids from fat content and specific gravity.

Such other physical properties as viscosity, surface tension, electrical conductivity, and refractive index also have been studied, and the contributions of the several milk constituents have been rather thoroughly defined.

Chemistry of Milk Processing

The various processes involved in manufacturing dairy products were developed empirically to preserve part or all of the nutrients of milk for consumption at a time or place other than that of production or in a form more desirable for a given purpose. Difficulties with physical stability and flavor often limit the utility of a product. Much of the current research in dairy chemistry revolves about the basic mechanisms of manufacturing processes and deteriorative changes in the belief that the problems can be solved by more complete and accurate knowledge. Interest in physical stability and flavor has evolved gradually; it was not prominent in 1906.

Heat is the most universally employed agent in milk processing. Our understanding of the effects of heat on milk has advanced greatly in the last half-century. The adoption of pasteurization on a wide scale led to many studies showing that the process does not seriously

impair the nutritive quality of milk. Conditions of pasteurization were established which would destroy the organisms causing tuberculosis but not interfere with creaming ability. In searching for a test for assessing the adequacy of pasteurization, various enzymes were examined and the test for phosphatase was finally adopted on the basis of work of Kay and Graham in 1933 (see review by Kay *et al., 9)*.

The effects of heat on the proteins of milk serum have been of great interest, particularly in the past 20 years. The work of Rowland showing the quantitative relationships between the extent of heating and the denaturation of these proteins marks an important milestone in this field. Interest in the denaturation of whey proteins has increased rapidly as they have been shown to be involved in such problems as cooked flavor, antioxygenic properties, cottage cheese quality, and the baking behavior of nonfat dry milk solids *(8)*.

A great deal of study has been made of the problem of heat coagulation of milk, which is so important in the evaporated milk industry. Much empirical knowledge has been accumulated on the effects of such variables as time, temperature, pH, concentration, and salt balance on the coagulation, but the basic mechanisms involved are not known as yet. The recognition by Sommer and Hart in 1919 of the importance of ionic balance in determining the stability of the caseinate particles was of utmost importance, not only in providing a basis for controlling heat coagulation but also in making it clear that salt balance must be considered in all aspects of the stability of caseinate. The painstaking work by Webb, Holm and coworkers of the U. S. Department of Agriculture over the period 1925-1945 defined the effects of the various variables in a multivariant problem. The stability of caseinate particles in all sorts of concentrated milks still poses one of the knottiest problems of dairy chemistry.

The precise mechanism of the action of rennin on milk has proved an elusive problem to decipher *(1)*. As long ago as 1875, Hammarsten expressed the view that the process consists of two stages, an initial attack of the casein by the enzyme and a subsequent gelation of the altered product under the influence of calcium ions. This general theory of a two-stage process has persisted, although ideas of the natures of the reactions have varied from time to time and, in general, confusion has reigned. Hammarsten himself and many later workers presented evidence that a fragment of casein (the so-called whey proteose) is split off by the action of rennin. Since crude rennin contains pepsin, the problem could not be studied effectively until rennin was finally crystallized by Hankinson in 1943 and Berridge in 1945 and the individual components of casein were identified and characterized. In the last decade the field has been reactivated with the assiduous work of Pyne, Berridge, Nitschman and others. Recent evidence indicates that the primary action of rennin is to split off a small peptide from α-casein. The resulting product is more sensitive to calcium ions and coagulates along with unchanged β- and γ-caseinates. The most modern ideas of the mechanism of the process are indeed reminiscent of Hammarsten's original proposal!

Gravity creaming was investigated seriously and thoroughly in the period from 1915 to 1944 *(4)*. Major interest was in the mechanism of formation of the cream layer in bottled market milk. After a number of workers had shown that the rate of formation of the cream layer could not be accounted for by the rise of individual fat globules, Troy and Sharp demonstrated in 1928 that it could be explained by the clustering of globules and the rise of clusters. Sharp and coworkers then proceeded to demonstrate that the clustering depends on the adsorption of a milk plasma constituent, an "agglutinin," on the surface of the globules in the solid but not in the liquid state. Sommer and coworkers confirmed this finding and actually isolated a milk protein fraction rich in the "agglutinin." The loss of creaming power on heating is attributed to alteration of the "agglutinin." These concepts have permeated the entire thinking in the field in regard to the behavior of fat globules under various conditions. Ironically enough, the mechanism of creaming was elucidated at just about the time that the widespread use of homogenized milk obviated the importance of "cream-line"!

The mechanism of the age-old process of churning has been the subject of considerable controversy during the half-century *(10)*. During the twenties and thirties a good deal was heard of the opposing emulsion reversal theory, first proposed by Fischer and Hooker in 1916, and the foam theory, suggested by Rahn in the twenties. Actually each of these theories described different aspects of the process, and the contrast between them was drawn too sharply. Careful microscopic work by King and others has established the structure of butter as consisting of plasma droplets, air, and fat globules dispersed in a continuous medium of fat. The stages of the process whereby the adsorbed lipoprotein is "eroded" from the surface of the globule and some of the fat is liberated have been reasonably well defined. An autoflotation process may be involved as postulated by van Dam and Holwerda, but there is not entire agreement on the precise nature of such a flotation. King has demonstrated characteristic differences in structure among butters made by various classical and continuous processes.

The deteriorative processes leading to off-flavors in milk and dairy products have been studied intensively. The objectives of such research have been the control or prevention of off-flavors, the elucidation of mechanisms in-

volved, and the isolation and identification of compounds responsible for the flavors.

Lipase has been shown to occur in all milks, but only a relatively few samples develop hydrolytic rancidity spontaneously. However, lipolysis can be "activated" in all samples by warming and cooling treatments and agitation, as defined by Sharp and coworkers, and by homogenization, as studied by Gould. These treatments presumably alter the fat globule substrate rather than the enzyme. The crux of recent interest in this problem has been whether any particular fatty acids are liberated preferentially. This question has not been settled. Lipolysis was studied a great deal in the thirties and early forties but since it did not develop under the usual conditions of handling market milk, interest then lagged until revived by the advent of pipeline milkers and bulk tank methods of handling, some of which promote lipolysis (see review by Herrington, *6*).

Oxidative deteriorations of the lipides of milk and milk products have been of great concern. The oxidation of milk fat itself is clearly involved in such products as butter, butter oil, and dry whole milk. It is apparently the phenomenon observed in the oxidation of fats in general (see review by Lea, *12*). A great deal of research has been done on prevention of oxidized defects, particularly by elimination of metallic catalysts, by addition of antioxidants, and by packaging in inert gas. The last method has proved to be by far the best means of preserving dry whole milk, at least from gross oxidation effects.

Oxidized flavor in pasteurized milk is an oxidative defect peculiar to the dairy industry. Although this defect was first mentioned about the turn of the century, extensive research on the chemistry involved did not begin until about 1930. This chemistry is still not completely understood, but a great deal has been learned about the factors affecting the development of oxidized flavor *(5)*. Thurston *et al.* suggested in 1935 that it arises primarily from oxidation of the phospholipides rather than of milk fat. This idea has been widely accepted, although recent work indicates that a number of reactions occur and that the milk fat itself may be involved. The importance of oxygen and copper was well established by work in a number of laboratories in the thirties, and in the 1940's experiments by Olson and Brown at West Virginia and Krukovsky and Guthrie at Cornell emphasized the key role of ascorbic acid.

A great deal of study has been devoted to the chemistry of the reactions involved in the browning of milk and milk products *(16)*. This phenomenon is of major importance in sterilized concentrated milks and also in dry milks, not only because of the color itself but also because of the flavors and odors associated with it. Browning occurs in many foods other than milk, and data obtained with them and with simplified systems are frequently applicable to milk. Pioneer work on the browning of milk was done by Orla-Jensen and Plattner in 1905 and Ramsey, Tracy, and Ruehe in 1933, who attributed it to a sugar-protein interaction. Such reactions seem, indeed, to be the major cause of browning. Webb and Holm in 1930 defined the effects of various variables on the rate of browning of fluid dairy products. From a practical standpoint the crucial factors are concentration and extent of heating. Study of the relationship of browning to time and temperature of heating has revealed the possibility of sterilizing concentrated milks with little or no browning. This possibility has not been realized as yet because difficulties with physical stability have not been overcome. Lea and associates in the late forties and early fifties elucidated the mechanism of browning in "dry" systems. Here the governing factor is moisture content.

Obviously it is impossible in a short article to do justice to a half-century's work on the chemistry of milk. The various phases that have been mentioned are, in the author's opinion, some of those that are of permanent value. Many problems await solution and new problems continually arise but the pace of research in the field, as in biochemistry in general, is accelerating. It may be expected that the next 50 years will witness a greater accomplishment than the past fifty!

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Progress in Basic Bacteriology of Milk

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At the very beginning, one must realize that advances in dairy bacteriology have paralleled and, in many instances, have been dependent upon advances in general bacteriology and other areas of applied bacteriology. As everywhere in science, new discoveries in fundamental fields may be quickly utilized to solve problems existing in areas often only remotely related to the original research. Additions to our knowledge of the taxonomy, nutrition, and physiology of microorganisms in general have been applied to other areas of bacteriology as soon as this information became available. Therefore, it must be emphasized that many contributions of a general nature fundamentally are responsible for the advances in the basic bacteriology of milk, and these contributions lie buried in the mass of literature on bacteriology and cannot be catalogued at this time.

J. J. Jezeski

The Changing Approach

During the early years of A.D.S.A., generally, dairy bacteriology research had its emphasis in the more descriptive aspects of the science. Various groups and species of organisms were being isolated and enumerated in studies both on defects which had been observed in milk and a variety of dairy products and on fermentations utilized in the manufacture of certain products. This was the period in which dairy bacteriologists were beginning to recognize a number of the organisms that were responsible for serious defects, as well as the complex starter and cheese fermentations. After isolation of a variety of these organisms, detailed studies on their morphological and cultural characteristics resulted in a fund of information which permitted many of these organisms to be classified in an orderly fashion.

Descriptions of easily cultivated organisms stimulated further work on the nutrition of more fastidious types of bacteria; as a result, improved techniques and media produced a greater understanding of many more organisms of importance in dairy bacteriology. Attention was then turned not to the sources of microbiologically produced reactions but to "why" and "how" they were produced. Such work included studies on both the precursors and end products resulting from undesirable as well as desirable changes in dairy products. This, in turn, has led to emphasis in the area of bacterial physiology and nutrition with detailed experiments being designed to determine mechanisms by which flavor and odor and appearance defects were produced.

It would appear that the purely descriptive approach has given way to that of detailed studies of bacterial metabolism as related to the nutrition and cultivation of microorganisms and studies of the physiological reactions taking place during the growth of microorganisms that are important in the manufacture as well as deterioration of a variety of dairy products. Not only has the effect of microorganisms on their environment been studied in more detail, but the effect of the environment, both physical and chemical, on the microorganism has received more attention.

To be sure, information has been, and is now being, collected which was impossible to obtain in earlier years because of the lack of tools of modern science, which presently are available. Micromethods including chromatographic procedures, other specialized analytical techniques, and the availability of isotopic tracer materials all permit studies on physiological reactions that were not possible in earlier years.

Some Wise Men

There were, in the course of studies in dairy bacteriology down through the years, instances of men wise beyond their times whose contributions have been unquestioned and which in reality were large advances along the frontiers of this scientific field—men who have pioneered in many studies of bacterial metabolism, nutrition, and physiology. As an example, the name, Orla-Jensen, is familiar in this regard, and he is recognized for his researches at the beginning of the 20th century. His keen interest in the lactic acid bacteria, their cultural and morphological characteristics, and their taxonomic relationships to other bacteria as well as among themselves is well known. In addition, his experiments in cheese ripening are among the earlier studies in bacterial physiology as applied to dairy industry. His classical monograph, *The Lactic Acid Bacteria,* has provided the bases for our modern concepts of the taxonomic and cultural characteristics of these organisms which are so important in dairy bacteriology. There have been, of course, some changes in nomenclature, and some of our concepts of these organisms have been changed as a result of more detailed studies on cultural and physiological characteristics of these bacteria; but in the main, this work published in 1919 has stood the test of time and has formed a background for our modern understanding of

the characteristics of this important group of organisms.

Dairy Bacteriology by Orla-Jensen, the second edition of which appeared in 1916, was translated into English in 1921. In this book the basic concepts of dairy bacteriology were clearly presented and the factors influencing the bacteriological quality of milk were very completely covered, and a rather surprising understanding of the concepts of the fundamental fermentations taking place in cheese ripening was demonstrated.

Also of note are the extensive contributions of Hammer and his coworkers, which resulted in a whole series of bulletins from the Iowa Agricultural Experiment Station at Ames. This work included the isolation and identification of a variety of microorganisms associated with defects in several dairy products and the significant studies on the production of flavor and aroma compounds from starter cultures, as well as precise description and differentiation of the associative aroma bacteria. Hammer's *Dairy Bacteriology,* which was published in 1928 and appeared in the second and third editions in 1938 and 1948, respectively, has been the standard textbook in dairy bacteriology and of use to both students and industry.

There have been others whose researches have stood the test of time and whose ideas were projected far beyond the level of their day. Limitations of space prevent even the mere mention of the many significant contributions; nevertheless, the accomplishments of far-sighted workers in the field of dairy bacteriology must be acknowledged and remain as milestones along the path of progress. In addition to advances in bacterial taxonomy, physiology, and nutrition there are important papers on the effects of the physical and chemical environment on microorganisms—particularly the effect of heat in killing bacteria and the action of chemical sanitizers.

Bacteriophage in the Dairy Industry

One of the most outstanding and clear-cut examples of progress in the field of bacteriology as applied to the dairy industry lies in a historical account of the problem of starter bacteriophage, which at the present time is considered to be one of the most important causes of slow acid production by starter cultures. It was about 1917 that the first published accounts of the bacteriophage phenomenon appeared. The first observations of D'Herelle on the bacteriophages of intestinal pathogenic bacteria were certainly the forerunner of all of the work in this field as well as a beginning of fundamental work which led to an understanding of the action of lactic bacteriophage in the dairy industry. It is significant that in the English translation of D'Herelle's *The Bacteriophage and Its Behavior* in 1926 there was only a casual reference to a bacteriophage specific for a streptococcus—a pathogen, *Streptococcus pyogenes.* It was not until the early 1930's that the Iowa State group obtained evidence that bacteriophage was active in lactic acid cultures; this discovery touched off intensive activity of a number of workers at Iowa State and in New Zealand. Their numerous researches published over a period of about 10 years brought this subject to the point where the phenomenon was fairly adequately described and conditions were defined which would permit control of the action of this enemy of starter culture. Sudden recognition of this problem in dairy bacteriology may have been partially the result of changes in modern methods of cheese manufacture by which a very large proportion of Cheddar cheese was being manufactured from heat-treated or pasteurized milk.

Development of Techniques — "Standard Methods"

Because of the extended use of various bacteriological procedures in the grading of milk and the great importance of enumerative procedures in the determination of quality in both raw and finished products, a discussion of the evolution of *Standard Methods* into its present form may be informative and interesting. Such a procedure provides excellent documentation of the various tests as they were used 50 years ago and how they were modified and others were adopted in the succeeding years. Thus, it is possible to get a clear-cut comparison of methods then and now; in short, an index of the development of working bacteriology as applied to the dairy industry down through the past 50 years.

The start—1905. This rather important work had its inception at the meeting of the laboratory section of the American Public Health Association in 1905 in Boston, Mass., where a committee was appointed to study the various methods used for the bacteriological examination of milk and to recommend uniform procedures. In 1907 and 1908, preliminary reports were prepared. The final committee report which was the first edition of *Standard Methods of Bacterial Milk Analysis* was published in the *American Journal of Public Hygiene,* **20,** (new series) 6: 315-345 (1910). Among the acknowledgments of cooperation and assistance made in this committee report were a number to people who were active in the early years of A.D.S.A.

From the very beginning the report included the usual definitions and precautions to be observed in the taking of samples and their care prior to laboratory examination; but of perhaps greater interest to the dairy bacteriologist are the actual methods as they were originally described.

The basic ingredients of the agar plating medium were peptone and an infusion from finely chopped lean beef. The reaction of the medium was determined according to Fuller's scale as a measure of acidity or alkalinity.

Special media mentioned included aesculin bile salt medium (liquid), lactose litmus agar, and whey agar. With respect to incubation of plates, two standard times and temperatures were optionally recognized: 48 hours at 37° C. and 5 days at 21° C. In the plating technique, the usual decimal dilutions were recommended in order to obtain a plate count in the range between 40 and 200 colonies. Interestingly enough, a quotation from the early report indicates the expectations with respect to the agreement between dilutions and duplicate plates: "Unless duplicate plates show as a rule approximately the same count, the worker should see if there is an error in his technique."

Microscopic examination of milk sediments was advocated for the purpose of estimating: *(a)* leucocytes, *(b)* number and morphology of bacteria, and *(c)* foreign matter and dirt. An elaborate procedure for centrifuging of a milk sample to gather the cellular constituents was advocated, and sediments were placed in a blood cell counter for the purpose of counting cellular material. The microscopic estimation of bacteria, likewise, was made by centrifugation to concentrate the sediment and the bacteria from the sample in a small glass tube fitted with a rubber stopper at each end. The sediment was driven down against a rubber stopper, removed and suspended in several drops of sterile water, spread over an area of four square centimeters, and then dried and stained with methylene blue. The recovery of bacteria was considered to bear a close relation to "the count obtained on a 1:10,000 dilution plate culture when grown in a saturated atmosphere at 37° C. for 24 hours on one per cent agar at a reaction of +1.5." The count per field multiplied by 10,000 was considered to approximate the number of bacteria per cubic centimeter of milk.

A section on tests for special bacteria was also included. Of the pathogens, both diphtheria and typhoid bacilli were mentioned, but typhoid was the only organism for which a special medium was suggested—lactose bile medium. Tubercle bacilli were detected by guinea pig inoculation followed by microscopic examination and/or tuberculin injection. Tests for gas-forming organisms included the Wisconsin curd test, glucose or lactose bile broth, and litmus lactose agar. Detection of long chain streptococci was made by microscopic examination followed by picking of typical colonies into broth and further microscopic examination.

Briefly summarized, the bacteriological methods recognized by the public health authorities and under which the industry grew were somewhat less elaborate and well developed than they are today. The plate count method for milk and cream was carried out with a rather ill-defined medium (from the standpoint of chemical composition), which was often laborious to prepare. Incubation of plates was at 37° or 21° C. for 2 or 5 days, respectively. Microscopic examination of milk sediment obtained by centrifugation was performed to estimate leucocytes, bacteria, and foreign matter. Tests were suggested for special bacteria, including typhoid and tubercle bacilli, long-chain streptococci, and gas-forming organisms.

Direct microscopic count adopted—1916. The second edition of *Standard Methods of Bacteriological Analysis of Milk,* published in the *American Journal of Public Health,* **6**: 12 (1916), was the first to recognize the direct microscopic examination of milk in approximately its present form, in which the 0.01-ml. pipette was used and direct smears of 1 sq. cm. were made. Xylol or gasoline was permitted as a defatting agent and 90% alcohol was used as a fixative. Fresh aqueous methylene blue was used as the stain and decolorizing was done in alcohol. The microscope was standardized by selection of the ocular or adjusting length of draw tube to provide a field diameter of 0.205 mm., the microscope factor thus being fixed at 300,000. In actual counting, the recommendation was to examine 30 fields. The direct microscopic method was not advocated as a method of estimating the numbers of bacteria present in milk samples but was considered suitable for grading raw milk where time was a factor.

The routine plating medium was changed to consist of beef extract and peptone and was essentially identical with that suggested for water bacteriology. However, only one time and temperature of incubation was considered standard, namely, 48 hours at 37.5° C., and it was at this time that the range of desired colony count, 30 to 300, was first adopted.

Of significance was the recognition that bacteriological analysis of milk might be required for two distinct purposes—namely, routine milk analysis and research, and that the standard methods as adopted for control work would not be sufficiently accurate for scientific investigation. Also, it should be noted that the second edition did not contain a section on tests for special bacteria or pathogens.

Reaction of media by pH measurement—1921. The third edition, *Standard Methods for the Bacterial Examination of Milk,* was published in 1921 and was the first to appear in a 24-page separate form rather than in a journal. Official recognition was given to microscopic counts made directly from unpasteurized milk, and Loeffler's methylene blue was recommended as the stain. With respect to standardizing the microscope, provision was made for the use of a special ocular micrometer in grading low count milk by which the field diameter was adjusted to 0.146 mm., and as a consequence the microscope factor became 600,000. The scope of the report also was increased to include the sediment test as an official method, and the detection of specific pathogens in milk was limited to detection of long chain streptococci associated with mastitis and chiefly by the direct microscopic method.

Of even greater importance from a fundamental standpoint, methods were presented for determining the reaction of media by using the hydrogen ion concentration measurement as expressed by the pH scale. The determination of hydrogen ion concentration colorimetrically by using brom thymol blue or brom cresol purple was adopted at this time. Methods of preparing agar were emphasized, and difficulties in obtaining media free of precipitates and extraneous material may be remembered by many people. The necessity for centrifugation or filtration was evident, and the troublesome method of filtration with the assistance of paper pulp represented a great deal of work that present-day techniques eliminate and which present-day workers do not fully appreciate.

The microscopic colony count of Frost, which was basically an agar plate method by which colony counts could be secured in a shorter time than with conventional plating techniques, also was listed as a provisional method.

Chemical methods introduced—1923. The fourth edition, *Standard Methods of Milk Analysis,* followed closely in 1923 because of the exhaustion of the third edition. This edition was the first to include a section on chemical methods prepared by the Association of Official Agricultural Chemists. The bacteriological methods were about the same as in the third edition with the exception that the ratio of counts obtained by the plate method to the count of individual bacterial cells by the direct microscope method was fixed at 1:4 instead of at 1:5. Also, the methylene blue reduction test was accepted as a provisional method.

Methylene blue test adopted—1929. In the fifth edition, which appeared in 1929, the section on the reaction of media was amplified to include several methods for the colorimetric determination of pH, and the standard incubation of plates was set for 48 hours at 37° C. In the direct microscopic count, the stain consisted of a saturated alcoholic solution of methylene blue in distilled water, rather than the Loeffler's methylene blue suggested previously. The section on counting and grading of milk by the direct microscopic count was greatly expanded and included discussions as to the number of fields necessary to get an accurate estimation of the actual count.

The methylene blue reduction method was accepted as an official method, and at this time the use of methylene blue tablets of constant strength was advocated. There was also a section on examination of centrifuged sediments for the purpose of determining cells, bacteria, and extraneous matter. But, again, the microscopic plate count (Frost method) was not recommended as a standard technique.

Initial methods for ice cream—1934. In the sixth edition, published in 1934, the bacteriology section had increased to 75 pages. In the direct microscopic examination of milk, the Newman-Lampert #2 stain combined the solvent, fixing, and staining procedures in one operation. The hydrogen ion concentration of the plating medium could be determined electrometrically or colorimetrically and the method of clarification of the medium was optional. It was a sign of progress with respect to the quality of media ingredients that clarification was not considered to be the problem that it had been previously.

A section on provisional methods described tests for (1) the presence of organisms of the *Escherichia-Aerobacter* group on the basis of a presumptive test made with brilliant green lactose peptone bile broth incubated at 37° C. for 48 hours. Coliform counts could be reported as most probable numbers as the result of using dilution extinction techniques; (2) sterility of bottles, cans, and other dairy utensils; (3) enumeration of thermophilic, psychrophilic, saccharophilic, and other types of bacteria that do not grow readily on standard agar at 37° C., which required 20° C. or 55° C. incubation and the use of a more adequate agar medium containing beef extract, peptone, glucose, tryptone, and yeast extract as nutrient materials; (4) the recognition of hemolytic streptococci by means of various media: blood agar, meat infusion broth and agar, glucose serum broth, and sodium hippurate broth; (5) determination of the number of bacteria in ice cream which permitted both the volumetric and gravimetric methods of measuring the sample. Directions for the Frost little plate and the Stewart-Slack procedures for sediment were omitted.

A new milk-containing medium—1939. The seventh edition, published in 1939 under the title *Standard Methods for the Examination of Dairy Products,* contained 117 pages in the bacteriological section. An important change consisted of the introduction of a new standard agar containing dextrose, lactose, and other milk solids, and a digested casein peptone. The change from the beef extract–peptone agar to the tryptone-glucose-extract-milk agar represented the first serious change in plating medium, which, as a consequence, improved the productivity of the medium and gave better recoverability of organisms present in milk. The controversies provoked by the higher counts obtained on the more productive plating medium will be well remembered, as will the difficulties encountered in counting the plates due to formation of precipitates produced by the milk solids added after autoclaving.

In the standardization of the microscope, the diameter of the field was not fixed and was left to the discretion of the operator. Both 6.4 and 10× oculars were permitted. For the first time there appeared a standard of the number of fields to be counted depending upon field diameter measurement (microscopic factor) and the range of expected microscope counts.

Tests for organisms of the coliform *(Escherichia-Aerobacter)* group were recognized as official, and presumptive media included brilliant green lactose bile broth, formate ricinole-

ate broth, violet red bile agar, and desoxycholate agar. In addition, methods for the completed coliform test were also presented which included the use of eosin methylene blue or Endo agar and lactose broth fermentation.

Methods suggested for pathogenic, usually hemolytic, streptococci also were given official recognition. A section was also included on the examination of milk for tubercle bacilli by utilizing direct microscopic, cultural, and animal inoculation methods. Procedures for detection of *Brucella* sp. in milk by utilizing the guinea pig inoculation and/or culture on liver agar or tryptose agar were described, as well as a method for the examination of milk for *Brucella* agglutinins.

A section was also added on the determination of yeasts and molds in butter by utilizing potato dextrose agar acidified with tartaric acid, and it was of interest to note that methods for the bioassay of vitamin D in milk were also introduced.

Detailed examination of frozen desserts and ingredients—1941. The primary purpose for the publication of the eighth edition in 1941 was to describe methods for the detailed examination of frozen desserts. The new material included methods for the examination of plain ice cream and other frozen desserts together with methods for the examination of common ingredients of frozen desserts, such as powdered milk, evaporated and condensed milk, dry milk, colorings, flavoring extracts, fruits, nuts, sweetening agents, and egg products. Methods for analysis of ingredients included the use of 55° C. incubation for cultivation of thermophilic bacteria and special media for the detection of thermophilic aerobes and anaerobes, particularly the flat souring spore formers, thermophilic anaerobes not producing hydrogen sulfide, and thermophilic anaerobes producing hydrogen sulfide.

Methods for the examination of milk, cream, and butter were revised. In the agar plate method, two temperatures of incubation were optionally recognized as standard, 32° C. or 37° C. for 48 hours. A short section on the resazurin test was presented for the first time but with no recommendation as to its acceptance. The methods for determination of sterility of bottles, cans, and other dairy utensils were enlarged. Rather elaborate methods for the examination of butter were introduced, including the determination of mold mycelia in butter, the Burri slant method for counting bacteria, and microscopic examination of butter (tentative).

Under special procedures for the detection of certain organisms, a provision was made for either of two methods of determining *Brucella* agglutinins—the test tube method or the rapid slide agglutination test.

Resazurin reduction test approved—1948. In the ninth edition, which appeared in 1948, the microbiological section had grown to 248 pages. The resazurin reduction test method was officially recognized, and methods for the bacteriological examination of stabilizers used in frozen desserts were introduced, as well as procedures developed by the Food and Drug Administration for determining the extraneous matter in dairy products. Significant revisions in the ninth edition were optional incubation of agar plates at 32° or 35° C. and hourly inversion of tubes during incubation for the methylene blue test. In cheese, directions were given for the isolation of pathogenic streptococci belonging to Lancefield's group A, *Brucella* sp., *Salmonella typhosa,* and other *Salmonella* sp., pathogenic *Shigella* sp., and enterotoxigenic staphylococci.

The tenth edition. In 50 years of progress our working knowledge has advanced to the point where the tenth edition of *Standard Methods for the Examination of Dairy Products,* published in 1953, contained 231 pages of material dealing with a large variety of products. Included were methods for the plate count, which permitted optional incubation of plates at 32° or 35° C. for 48 hours and utilized two milk-free plating media of somewhat different compositions whose productivities were somewhat similar to the old milk-containing medium. These media may be routinely made up, require little or no clarification, and optionally are available in dehydrated form. The direct microscopic method in its present familiar form permits the use of either the conventional 0.01-ml. pipette or a syringe to measure the sample and a choice of either the acid-and-water-free, aniline oil methylene blue, or polychrome methylene blue stains. Also, the methylene blue and resazurin reduction tests have been given official recognition. Improved dilution procedures for dried milk products were also presented.

Special consideration has been given to the determination of psychrophilic, thermophilic, and thermoduric bacteria. Tests for special bacterial groups or species in milk and cream include those for the coliform *(Escherichia-Aerobacter)* group, pathogenic streptococci—usually beta hemolytic, tubercle bacilli, and *Brucella* sp. Agglutinins for *Brucella* species may be determined by test tube or rapid slide procedures or the newly introduced milk ring test on pooled samples.

Microbiological methods for butter cover the determination of yeast and mold count, mold mycelia counts, and the Burri slant method for estimating bacterial content. In studies on frozen dessert ingredients, particularly sweetening agents, procedures are given for the estimation of thermophiles, flat-sours organisms, and thermophilic anaerobes producing hydrogen sulfide and nonhydrogen sulfide–producing types in addition to methods for other microorganisms previously mentioned. Isolation of pathogenic bacteria from cheese includes methods for pathogenic streptococci of Lancefield's Group A, *Brucella* species, *Salmonella typhosa* and other

species, *Shigella* species, and enterotoxigenic staphylococci.

The Contributions of Dairy Bacteriology

These developments in methods typify and summarize the progress in some areas of working bacteriology as applied to the dairy industry down through the past 50 years. Of the dairy bacteriologists, the name of R. S. Breed has been most directly and closely associated with the evolution of *Standard Methods*. The early works of H. W. Conn and H. L. Russell on the bacterial flora of milk and its sources were among those that stimulated the original interest in uniform methods for determining the bacteriological quality of milk. Many other persons well known in the ranks of ADSA as committee members and referees have contributed time and effort in the development of uniform and critical procedures.

In general, the contributions of dairy bacteriologists have consisted of the control of deteriorative action by microorganisms, and secondly, increased knowledge concerning the productive activities of the organisms used in the manufacture of certain products. The association of a defect with the presence of a microorganism or group of microorganisms made it desirable to obtain detailed information on certain of their properties and a knowledge of factors controlling the presence or growth of these organisms. These studies have resulted in improvements of the keeping quality and shelf life of a number of products. The increased knowledge concerning starter cultures—the common as well as special types of organisms and the factors influencing their activities—has resulted in significant changes in manufacturing processes from the standpoint of improved and more uniform quality and economic production. Furthermore, time-saving manufacturing procedures have been developed and more vigorous and direct merchandising and selling methods were made possible.

A measure of the importance of these contributions in dairy bacteriology and the significance of their value to the industry lies in the recognition that has come to various workers who have specialized in this field. The esteem with which these advances have been held may be indicated by the fact that some of the winners of the Borden Award in dairy manufacturing have devoted much or all of their efforts to dairy bacteriology.

To give credit where it is due, it is both fitting and necessary to point out the parallel roles that other branches of science and technology have played in solving problems of bacteriological origin in the dairy industry. The contributions of engineering and certain areas of dairy technology in the production of new equipment and the design of new processes should be acknowledged. The bacteriologist alone may claim credit for isolation and detailed study of a great variety of microorganisms, but the control of their activities on an industrial basis must be shared with others.

In terms of final goals and objectives, the horizons are never reached. In this unending journey, it is easier perhaps to measure the distance traveled than how far progress has yet to go. This measurement may be done on the basis of past accomplishment and is recorded in the scientific literature. The distance yet to be traveled is difficult to estimate.

An Evaluation of the Balance of Nutrients in Milk

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Chemical advances in the nineteenth century largely made possible the development of the science of modern nutrition. After the chemists discovered proteins, good nutrition demanded something more than meeting caloric requirements. A more detailed study of the amino acids established variability in composition of proteins from different sources and introduced the concept of quality of protein. As the ash of milk was found to contain essential nutrients, further experiments designed to study inorganic elements in nutrition revealed that milk contained essential food constituents not found in the known carbohydrates, proteins, fats, and salts *(51)*. Prior to 1906, it had been suggested that scurvy and beriberi in humans were caused by specific dietary deficiencies, but this view was not universally accepted. The production of experimental scurvy in the guinea pig *(42)* and a disease resembling beriberi in pigeons *(21)* provided the important laboratory approach to the solution of the nutritional problems of humans. Experiments whose objective was to define the nutritionally important components of milk by using laboratory animals coupled with investigations of the human deficiency diseases firmly established the need for trace quantities of organic chemicals.

D. M. Carlson R. G. Hansen

Funk introduced the concept of "vitamine" in 1911 *(25)* to describe the missing organic factors necessary to cure beriberi and scurvy and to complete the diets of laboratory animals fed purified carbohydrate, protein, fat, and salts. During the past 44 years numerous new essential nutrients have been discovered, including certain essential amino acids and fatty acids, other vitamins, and trace minerals. Throughout the period when our modern concepts of nutrition were developing, milk has been looked upon with favor by nutrition workers because most of the food elements needed by man are found in good balance in milk.

Preceding and paralleling these advancements in our knowledge of nutrition have come important developments in chemistry and chemical technology. The organic chemist has been able to synthesize most of the essential organic food constituents, in some cases on a commercial scale. Synthetic products have been employed for improvement of the balance of nutrients in our food supply *(59)*. There is reason to expect improvements in chemical technology to the point that most, if not all, of the critical essentials may be supplied in synthetic form to supplement any deficiencies that may exist in the natural food supply.

Advances in food technology have also brought about the development of plant products which compete with dairy products. This competition has forced the dairy industry to reexamine all of its products and to think seriously in terms of supplying its nutritionally sound foods at competitive prices. Fortunately, the cow is highly efficient in her conversion of roughages unsuitable for human consumption into products which are useful foods for man *(9)*. This efficiency coupled with the balance of nutrients in the product is the best argument for her future in meeting the demands for a balanced diet for expanding populations.

Many of the people of the world are unable to obtain sufficient food for good health and resistance to disease. The first consideration for them is to get enough calories. In areas of the world where the food supply is adequate there is the problem of selecting the proper foods to provide a balanced intake of the required nutrients. Tables of recommended dietary allowances prepared by the Food and Nutrition Board of the National Research Council *(60)* and the minimum daily requirements of nutrients formulated by the U. S. Food and Drug Administration are most useful guides to help with this problem. The recommended allowances are based upon clinical observations and upon an evaluation of the facts obtained by nutrition experiments with laboratory animals. The usual practice is to take the values obtained experimentally and increase them to obtain a recommended value. The purpose of this increase is to provide a margin of safety to insure adequate nutrient intake to meet various situations. These allowances serve as a useful guide for most of the population, but there is some evidence that sick, wounded, or convalescent

patients may need levels of nutrients in excess of those recommended. Along with these general recommendations for adequate levels of nutrient intake, is the primary problem of a balanced diet. Calories, carbohydrate, protein, fat, minerals, and vitamins must be considered with respect to each other. In other words, good nutrition demands a balanced intake of the various essential food constituents.

The new-born mammal obtains its food from the milk produced by maternal mammary glands. The circumstance for which this milk is produced requires it to be nearly complete from a nutritional standpoint. Its natural quality as a food has led to the production of a wide variety of products for the use of humans of all ages.

Composition of Milk

The composition of cow's milk depends somewhat upon breed, feed, period of lactation, and processing conditions. For the purpose of a discussion of nutrition, results of some typical analyses are given in Table 1. First is given

TABLE 1
General composition of milk[a]

	Fat	Protein	Lactose	Ash
		(Per cent)		
Cow's milk	3.7	3.3	4.8	0.72
Holstein	3.6	3.4	4.9	0.68
Ayrshire	4.1	3.6	4.7	0.68
Brown Swiss	4.0	3.6	5.0	0.73
Guernsey	5.2	4.0	4.9	0.74
Jersey	5.2	3.9	4.9	0.70

[a] The values for cow's milk were taken from reference *58* and those for the individual breeds from reference *63*.

the composition as listed in the National Research Council publication *(58)*, followed by values obtained in one herd for the individual breeds *(63)*. The breed variations are quantitative rather than qualitative. Milk contains all the classical compounds of biochemistry, that is, proteins, carbohydrates, lipids, minerals, and vitamins. These nutrients will be considered individually.[1]

Proteins

Chemically, the proteins are complex polymers of 18 individual amino acids in various combinations. Feeding experiments now have demonstrated that man requires daily supplies of at least 8 of the 18 amino acids for maintenance of normal body functions during adult life *(66)*. For adequate nutrition, proteins must supply enough of the essential amino acids. A protein deficient in one of the essential amino acids will not permit nitrogen equilibrium no matter how much of the protein is consumed. Therefore, the efficiency with which dietary proteins are utilized will vary depending on the similarity between the amino acid composition of the dietary protein and the amino acid pattern required by the animal. The concept of biological value of a protein can be related to its amino acid composition. Animal proteins on the whole are better sources of essential amino acids than plant proteins; therefore smaller amounts of protein are required when meat, fish, eggs, cheese, and milk are eaten than when the foods selected consist largely of cereals and food of plant origin *(6)*.

The specification of a recommended protein intake is subject to uncertainty because of the differences which exist in protein quality, largely due to their amino acid composition, and because requirements for protein are greater for growth, tissue repair, pregnancy, and lactation. In terms of protein for children, recommended intakes are as high as 3.5 g/kg of body weight in infancy and decline to 1.5 g/kg in late childhood *(60)*. The National Research Council publications also have specified that 1 g. of protein should be consumed per day for each kilogram of weight for adult men. For the average woman this allowance is slightly more, 60 g. of protein for 56 kg. of body weight, with allowances increased up to 100 g. for pregnancy and lactation. Presumably these allowances are sufficiently liberal to provide for variations in amino acid composition of the proteins and assume an intake of a variety of foods including some of animal origin. There is also a liberal allowance to meet individual differences that exist.

One of the important developments of the last two decades has been the definition of requirements for dietary levels of the essential amino acids for maintenance of nitrogen equilibrium in the adult *(66)*. The amount of each amino acid required for nitrogen equilibrium has then been doubled to give a margin of safety for recommended daily intake. These amounts compared with analytical values for milk (Figure 1) indicate that if no protein other than that contained in one quart of milk is consumed, the requirements for the essential amino acids are met for the normal adult. The requirements for amino acids, as illustrated in the figure, apply principally to a normal man of an average size or approximately 150 lb. weight. Insufficient information is available to establish the requirements for amino acids for such special functions in the human as growth, pregnancy, lactation, and tissue repair as encountered after periods of surgery or physical injury. Such specialized conditions do demand additional protein intake.

Analytical values now available for the amino acid composition of purified proteins of milk indicate important differences (Table 2). Some nutrition experiments refer to commercial prep-

[1] An extensive bibliography of the nutritive value of milk and milk products is found in the paper of Kon and Henry *(47)*.

TABLE 2

Amino acid analysis of bovine milk proteins[a]

	Grams amino acid per 100 g. of protein						
	Casein proteins			Serum (whey) proteins			
	α-Casein	β-Casein	γ-Casein	β-Lacto-globulin	α-Lactal-bumin	Immune globulins (euglobulin and pseudo-globulin)	Serum albumin
Approximate per cent of total milk proteins *(65)*	45-63	19-28	3-7	7-12	2-5	1.4-3.1	0.7-1.3
Glycine	2.8	2.4	1.5	1.4	3.2	5.2[c]	1.8
Alanine	3.7	1.7	2.3	6.2	2.1	4.8[c]	6.3
Valine	6.3	10.2	10.5	5.8	4.7	9.6	5.9
Leucine	7.9	11.6	12.0	15.6	11.5	9.6	12.3
Isoleucine	6.4	5.5	4.4	8.4	6.8	3.0	2.6
Serine	6.3	6.8	5.5	5.0	4.8	11.5[c]	4.2
Threonine	4.9	5.1	4.4	5.9	5.5	10.5	5.8
Lysine	8.9	6.5	6.2	11.4	11.5	6.8	12.8
Arginine	4.3	3.4	1.9	2.9	1.2	4.1	5.9
Methionine	2.5	3.4	4.1	3.2	1.0	0.9	0.8
Cysteine + half-cysteine	0.43	0.1	0.0	3.4	6.4	3.2	6.5
Aspartic acid	8.4	4.9	4.0	11.4	18.7	9.4[b]	10.9
Glutamic acid	22.5	23.2	22.9	19.5	12.9	12.3[b]	16.5
Tyrosine	8.1	3.2	3.7	3.8	5.4	6.7[b]	5.1
Phenylalanine	4.6	5.8	5.8	3.5	4.5	3.9	6.6
Tryptophane	1.6	0.65	1.2	1.9	7.0	2.7	0.6
Histidine	2.9	3.1	3.7	1.6	2.9	2.1	4.0
Proline	8.2	16.0	17.0	4.1	1.5	10.0[b]	4.8
Total[d]	115.7	117.4	113.3	113.9	111.6	116.3	113.4
Reference No.	28	28	27	8	29	78, 35, 41	79

[a] The eight proteins in this table account for about 97% of the total proteins and about 90% of the total nitrogen present in normal milk.

[b] Figures taken from the amino acid analysis of the immune pseudoglobulin of colostrum which is closely related to, or the same as, that of milk *(35)*.

[c] Unpublished data on the immune globulins of colostrum *(41)*.

[d] In some cases values for phosphate and amide N (as ammonia) are included in the totals.

The authors are indebted to Dr. B. L. Larson for preparation of this table.

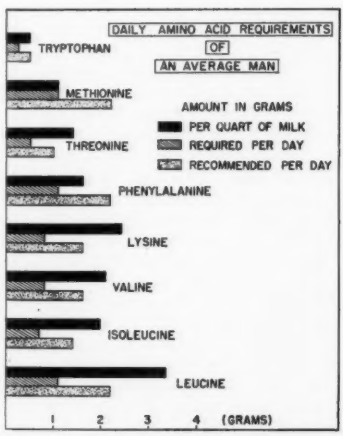


FIG. 1. Daily amino acid requirements of an average man. Amino acid values from reference *58*. Recommended daily intake of the amino acids from reference *66*.

arations which may contain varying proportions of the individual proteins of milk. Consequently it would be necessary to have an amino acid analysis of the particular product to adequately assess its nutritional value. In this regard the report of the committee on nomenclature of milk proteins *(44)* should help to encourage a definition of the fractions wherever possible and should promote the standardization of products for nutritional studies. The analytical values for the amino acids in milk recorded in the National Research Council Bulletin 254 *(58)* agree surprisingly well with the values calculated from the amino acid analyses of the individual proteins (Table 3).

Creeping into nutrition literature is a tendency to use ratios of some of the essential amino acids to a denominator such as tryptophane, in order to graphically illustrate nutritional values of proteins. Although this practice may have merit, it also has some rather severe limitations. If the proportion of tryptophane in the protein is low, the other amino acids appear good by comparison. On the other

TABLE 3
Essential amino acids in milk

	Purified milk proteins[a]		Milk[b]	
	(% of protein)	*(g. per quart)*	*(% of protein)*	*(g. per quart)*
Tryptophane	1.6	0.50	1.5	0.47
Methionine plus cystine	3.5	1.10	3.5	1.10
Threonine	5.0	1.57	4.6	1.45
Phenylalanine	4.7	1.47	5.2	1.63
Lysine	8.3	2.60	7.8	2.46
Valine	7.2	2.38	6.9	2.17
Isoleucine	6.0	1.88	6.4	2.01
Leucine	9.7	3.04	10.8	3.38

[a] Calculated from the amino acid analyses for the individual proteins listed in Table 2.

[b] Calculated from National Research Council Publication 254, pages 68 and 69, (Reference *58*).

hand, if the proportion of tryptophane is high, the other amino acids appear correspondingly poor. Using such a technique coupled with dubious values for these amino acids in milk, Albanese *et al. (1)* have arrived at the startling conclusion that milk may be deficient in lysine. Available evidence *(5, 58)* indicates that milk is an excellent source of both tryptophane and lysine with a ratio approaching 1 to 5.5. This ratio is, in fact, near that which Albanese considers optimum.

Results of experiments with animals often serve as useful criteria to evaluate human needs. Expressed in terms of total protein, regardless of protein level, the lysine requirement of rats and pigs is 5 to 5.5% of the protein *(53)*. If one expresses the lysine requirement as per cent of the diet for growth in weanling rats, it is approximately 1.0% *(67)*. Or relatively, if one considers the tryptophane requirement expressed as 1, the lysine requirement can be expressed as 5 times the trytophane requirement. A diet composed of liberal quantities of milk may contain 18% protein, or in a diet containing practically all milk, such as that consumed by the younger infant, the protein value may go much higher. In either case it is evident that the lysine intake is well over 1% of the total diet, and greater than 5.5% of the protein supplied (Table 3). It is also evident that the tryptophane intake is more than adequate to meet growth requirements. In spite of this there are those who claim that milk is deficient in lysine for optimum growth of infants *(1)*. The evidence at hand would indicate that this claim needs careful study. Further evidence is needed to get exact comparisons of human needs for growth and for maintenance of nitrogen equilibrium. One of the important problems in nutrition in the future concerns the determination of exact protein and amino acid requirements of various mammals, and man in particular, for these various conditions.

In laboratory growth tests there is evidence that the balance of amino acids can be disturbed by the addition of an excess of one of them *(36, 40)*. This disturbed balance may be reflected in an inability to properly utilize some of the other amino acids. The end result of this imbalance is impaired growth. Whether this presents a problem for practical consideration in human nutrition cannot be properly assessed with available evidence, but it does suggest caution in the indiscriminate addition of amino acids to human diets until adequate testing indicates the advisability.

Unbalanced amino acid mixtures which lack one or more of the essential amino acids have been fed to rats, and the supplements of the amino acids required to produce a balance have been fed after the elapse of various intervals of time *(10, 26, 71)*. In comparison with control animals fed complete mixtures, the growth was poor. Apparently protein synthesis is impaired. Incomplete amino acid mixtures deficient in essential amino acids cannot be used for protein synthesis, as they are not stored in the body for sufficient periods of time to allow the amino acid deficit to be made up hours later. Therefore, the formation of protein molecules is a coordinated tissue function and can be accomplished only when all amino acids that take part in the formation of the protein are present at the same time. To be effective, a protein must be complete with respect to its content of all the amino acids, and it is important that these complete amino acid foods be ingested simultaneously. The balance of the amino acid composition explains in part why proteins of an animal origin have a high nutritional value.

The supplemental value of one protein to another should also be mentioned. Frequently one food may complement another in that the essential amino acid balance is improved with a combination of foods; to illustrate: in cereal grains lysine is generally low, whereas milk contains an abundance of lysine. Simultaneous ingestion of milk with cereal grains improves the protein quality of the combination *(38)*. Such proteins fed simultaneously result in better growth of rats than when they are supplied at separate feedings. This also further substantiates the necessity of feeding well balanced proteins at all times.

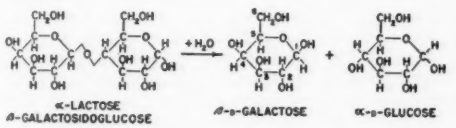
People residing in the tropical regions of the world who rely heavily upon a vegetable diet for their food encounter difficulty owing to protein deficiency *(81)*. Kwashiorkor is the native name for this deficiency. Kwashiorkor is thought by some to occur in every country in the tropical belt and it may occur in some areas in the temperate regions. Severe cases which are easy to diagnose are uncommon, even in the most seriously affected regions and at the most susceptible age, that is, the second year of life. The most conspicuous symptom of acute protein malnutrition is edema, or an accumulation of fluid and swelling. The victim slowly loses

energy and appetite. He is able to eat very little and passes loose stools contaminated with undigested food. Eventually the face and legs become swollen with fluid, hair color and curl are lost, and rashes break out on the skin. It is frequently seen in infants that have been weaned from mother's milk to an unbalanced diet. Doubtless other deficiencies and infections play their part, but many experts now believe that the principal cause of this failure of growth in body and development of intelligence is an inadequate intake of protein. Powdered skim-milk is an effective treatment for patients suffering from this disease.

Protein is the most expensive dietary item for the human consumer. Some nutritionists consider protein to be a limiting nutritional component during growth and pregnancy. Although the supply of protein foods may become critical during wartime or in times of population stress, adequate protein foods are available in the United States at present for people of almost every income level. Rarely, if ever, should protein deficiency be encountered in this country. Education is needed, however, to insure selection and consumption of proper food for all situations.

Lactose

Prior to 1906, Emil Fischer had discovered that the disaccharide, lactose, could be hydrolytically cleaved into two hexoses, galactose and glucose. The milk of mammals is characterized by its content of lactose as the principal carbohydrate component.



Only recently has it been appreciated that lactose may occur elsewhere than in milk. Neuramine-lactose was recently isolated from mammary gland of rats *(82)*. The detailed structure of this compound has not been established. Lactose has also been isolated in such diverse places as the blood of chicks *(70)* and from partial hydrolyzates of polysaccharides extracted from microorganisms *(69)*. The β-galactosido-glucose linkage may exist then as a component part of a variety of polysaccharides.

As to the occurrence of the hydrolytic products, little needs to be said about the glucose portion. The chemistry of glucose and its naturally occurring polymers has been the subject of research effort which has now become classical. Galactose occurs in plant and animal tissues as well as in milk. It is a frequent constituent of oligosaccharides, occurring in such compounds as melibiose and raffinose *(64)*. A number of plant gums and mucilages such as agar and gum arabic yield galactose upon hydrolysis. In animal tissues it is particularly noteworthy that galactose occurs abundantly in brain and nervous tissues. A group of substances known as the cerebrosides, found in nervous tissue, yield upon hydrolysis fatty acids, sphingosine and D-galactose. Galactose has recently been isolated from hydrolyzates also containing phosphate esters of inositol *(39)*. Presumably it is linked to the inositol through carbon number 1 of galactose to phosphate.

Although the function of lactose in the diet of the mammal is only partially appreciated, there are at least two aspects which need consideration. First are effects due to the influence of lactose itself upon gastrointestinal pH and motility *(23)* and, secondly, effects due to the unique nutritional behavior of the galactose portion. The effect of lactose upon gastrointestinal motility and pH is a reflection of the intestinal flora promoted by the presence of this sugar. The intestinal synthesis of lysine and histidine by the rat *(37)* and B vitamins by the cotton rat *(3)* and the sparing of B_6 in the nutrition of the chick *(84)*, all in the presence of lactose, must be explained by its effect upon pH and microflora. Lactose favors the utilization of calcium, probably by a similar mechanism *(24, 54, 55)*.

Enzymes that cleave lactose hydrolytically are termed lactases or β-galactosidases. Such enzymes occur not only in the digestive tract of mammals but also in various microorganisms and in plants. In the normal course of metabolism in mammals, the hydrolytic products, D-glucose and D-galactose are utilized for energy and synthetic processes. Glucose differs from galactose only with respect to configuration of carbon atom 4 of the molecule. The α and β forms of the two sugars are readily interconverted in aqueous medium and appear to present no nutritional problem to the living cell. This may be readily explained by the intermediate existence of an aldehydo form of the sugars. The manner in which energy is derived from glucose will require no elaboration here. The metabolism of galactose, however, has received less attention. Only recently have studies begun to reveal the metabolic pathways which galactose follows. One of the first indications came when Kosterlitz isolated galactose-1-phosphate from the livers of rabbits fed galactose *(48)*. It was subsequently shown that the first product of enzymatic galactose phosphorylation was galactose-1-phosphate *(83)*.

1. ATP + α-D-galactose $\rightarrow$ ADP + α-D-galactose-1-P

Further work based upon an elaboration of this observation and some carbohydrate balance studies in yeasts meabolizing galactose enabled Kosterlitz to predict that galactose-1-phosphate was converted to glucose-1-phosphate, a normal metabolite of glucose *(49)*.

A more detailed study of the metabolism of galactose by the yeast *S. fragilis,* revealed a

new coenzyme, uridine diphosphate glucose (UDPG) *(11, 50)*. The conversion of galactose-1-phosphate to glucose-1-phosphate could then be visualized:

2. Gal-1-P + UDPGlu ⇄ Glu-1-P + UDPGal
3. UDPGal ⇄ UDPGlu
Sum: Gal-1-P ⇄ Glu-1-P

An alternative series of reactions to account for this interconversion was also postulated *(62)*:

4. Gal-1-P + UTP ⇄ UDPGal + PP
5. UDPGal ⇄ UDPGlu
6. UDPGlu + PP ⇄ UTP + Glu-1-P
Sum: Gal-1-P ⇄ Glu-1-P

Reactions 3 and 5 are identical and the occurrence of UDPG has now been established on a sound basis both in microorganisms *(50)* and animal tissues *(52)*. Diphosphopyridine nucleotide has recently been shown to be required for this reaction *(52, 68)*. An understanding of the mechanism of the participation of DPN in this reaction will reveal the additional reactions that should be written to describe the interconversion of these esters. Reactions 2 and 3 are consistent with data obtained from *L. bulgaricus,* as UTP is not required for galactose-glucose interconversion in isolated preparations from this organism *(33)*. Reaction 6 has been well established *(57)*, but the status of reaction 4 in animal tissues remains in doubt at the present time.

Some animals have only a limited ability to tolerate lactose and galactose in their diet. One of the important factors which limits lactose utilization seems to be its effect on gastrointestinal motility *(23)*. Apparently there are species differences and other factors which influence the level at which lactose produces diarrhea, but the symptom itself is generally observed in both mammalian and non-mammalian species. Mitchell and Dodge *(56)* reported that high levels of lactose and also galactose in rats caused the development of cataracts. In this case, therefore, the effects of lactose can be differentiated to include *(a)* the effect of lactose on gastrointestinal motility and *(b)* the effect of galactose formed by the hydrolysis of lactose on the production of cataracts. Other manifestations of galactose toxicity have been reported. Ershoff *(22)* found that if the ration of rats was restricted solely to glucose and galactose there developed a paralysis in the hind limbs of all animals. These symptoms were not observed when the animals were given only glucose. When only galactose was fed, the animals died before the condition developed. After a rather exhaustive study of galactose metabolism in laboratory animals, Handler *(32)* concluded that galactose in excess in some way interferes with normal carbohydrate metabolism.

Chicks can grow and develop normally on purified diets devoid of galactose, indicating a capacity to form the amounts necessary for the nervous tissue to complete the structure of such compounds as the cerebrosides. Dam *(13)* reported that feeding a diet high in galactose to chicks produced nervous symptoms similar to those observed in vitamin B_1 deficiency. Rutter *et al. (70)* reported that although lower levels were tolerated by chicks, the inclusion of 15% galactose in purified diets caused typical nervous symptoms. Galactose occurred in the blood at all levels fed. At the 15% level of galactose feeding, blood galactose equaled the glucose level, and in addition traces of lactose were found. It has more recently been shown *(34)* by isolation techniques that hexose-containing uridine nucleotides are abnormally high (about double) in liver tissue as a result of galactose ingestion by chicks. Although glucose is more abundant in UDPHexose isolated from normal tissue, galactose also occurs. In chicks showing symptoms of galactose toxicity the concentration of UDPGalactose is increased and in some cases may be practically the only sugar component of this derivative of uridine. This finding may have some practical consequences in terms of understanding the causes of the toxic symptoms seen in other animals and humans.

Galactosemia appears to be a rare inborn error in the galactose metabolism of humans *(80)*. About 40 cases have been described in the medical literature *(2)*. This disease is characterized by the excretion of galactose when lactose is ingested. It is further characterized by enlargement of the liver and spleen, the development of eye cataracts, and dementia. Mild cases appear to recover spontaneously. The extreme cases of galactosemia in humans terminate in death if not properly diagnosed. When this disorder is diagnosed at an early age and lactose is removed from the diet, recovery is rapid and the symptoms are largely reversible. Holzel and Komrower *(43)* have found that parents of galactosemic children also have a low galactose tolerance; upon injection of a standard dose of galactose the blood levels of this sugar are higher than normal and persist for a longer period of time. It has recently been demonstrated *(45)* that the Gal-1-P-UDPGlu transferase enzyme (reaction 1 above) is missing in red blood cells and in the liver of galactosemic children. This explains their inability to efficiently utilize galactose although it does not explain why only part of the ingested galactose is excreted. The obvious suggestion is that there exist alternate pathways for the metabolism of galactose, such as the sequence of reactions 3, 4, and 5 above, which do not require the missing transferase. An oxidative pathway for galactose utilization in microorganisms has recently been reported by Douderoff *et al. (19)*. Further work will be required to determine if this alternate reaction system is of importance in galactosemic animals and humans.

The extent of galactosemia in the human population is not easily assessed; however, it fortunately appears to be rare. From a nutritional standpoint, it appears that pediatricians should be ever alert to the obvious symptoms, and, as adequate tests are available to diagnose the condition, immediate replacement of lactose in the diet provides an effective control measure. The most serious problem confronting human nutritionists is concerned with the possible irreversible nature of some of the symptoms of the toxicity *(12)*. The dairy industry is obligated to obtain more concrete and useful information in this regard.

Gaucher's disease is a constitutional abnormality with a strong family tendency *(20)*. In patients suffering from this disease, enlargement of the spleen occurs and the liver, osseous system, and lymph nodes also are involved *(85)*. An excess of cerebroside is deposited in the spleen, which is not the customary kerasin but contains glucose in place of galactose *(14, 30, 46)*. There is no evidence that the brain cerebrosides of patients with Gaucher's disease vary from the normal galactose-containing type *(85)*. This suggests a defect in one of the enzyme systems required to form galactose in the spleen.

The advantages of milk as a well-balanced food in the diet far outweigh the disadvantages to the few people who are sensitive to lactose. These studies serve to emphasize the importance of good medical practice in the early nutritional life of the population.

Milk Fat

Much of the emphasis of the research sponsored by the dairy industry has been devoted to understanding the role of the lipids in the diet. This reasoning has been justified by the economic position of the fat; that is, the butterfat test has received prime attention in buying milk from producers. A discussion of the merits of this pricing practice is of no direct consequence to the purposes of this paper. It is sufficient to emphasize the fact that from a nutritional standpoint the trend toward fully recognizing the other important milk components, for marketing purposes, is to be encouraged.

The contribution of the lipids to the flavor of dairy products is a basic consideration that demands additional comment. There is little doubt that in areas and in times of plenty, one of the most important appeals to the consumer is flavor. The competitive nature of the markets has improved sanitary practices and consequently the flavor of dairy products. Although this situation has undoubtedly hurt many small producers economically, one good result is the improvement in quality which the competition has forced. Unquestionably, properly prepared and handled butter is preferred to its competitive products from the standpoint of flavor. This is demonstrated by the recent increase in per capita sales of butter in spite of the price differential.

The nutritional implications of the lipids have received considerable attention *(4, 15)* during the past half-century. It is only necessary to mention here that some nutritionists consider the consumption of excessive amounts of fat to be a problem in atherosclerosis that merits consideration in evaluating the dietary patterns of humans *(61)*. The suggestion is that the total level of dietary fat and not the cholesterol is most important. Whatever the case, there is a tendency to overestimate the contribution of milk to the total level of fat in the diet.

It has been established that under highly defined experimental conditions a superior growth performance can be observed with milk fat when compared to other fats *(72)*. This difference in growth has proved complicated to define, but it is favorably influenced by the presence of lactose in the diet *(7)*. Under other conditions equal growth-promoting properties have been observed with milk fat and vegetable fats *(18)*. The coefficient of digestibility of both of these fats in animals is over 90% *(16)*. The practical consequences of these findings in human nutrition where variety is the dietary rule are not evident, but one might predict little, if any, difference due to the fats mentioned.

A further consideration relates to special dietary factors. Those recognized as vitamins are discussed under the appropriate section. Unsaturated fatty acids, some of which have been demonstrated to be important in the nutrition of animals and humans, are found in milk fat. Some additional factors thought to be important in nutrition have also been reported to be in milk fat *(17)*. If such factors do exist, it is unrealistic to hope that they may be found only in milk fat and further to assume that industrial chemists will not be able eventually to provide them synthetically if a critical need should arise.

Vitamins

As numerous discussions of the chemistry and biochemical function of the vitamins appear each year, the scope of this survey should include only some of the implications specifically pertaining to milk. Again, representative values have been chosen from the literature to serve as a basis for reference. Where the National Research Council has made recommendations for daily allowances of specific vitamins, these are also given.

Milk has been used as the vehicle for fortification of the diet with vitamin D. A level of 400 I.U. per quart appears to be satisfactory *(73)*. Although the vitamin A content of milk is somewhat variable owing to differences in dairy feeding practices, when one compares the average composition with the recommended intakes, it is apparent that milk contributes appreciable quantities of vitamin A to the diet (Table 4). Recommendations have been made for riboflavin, thiamine, nicotinic acid, and ascorbic acid. Properly processed and handled

TABLE 4
Vitamins in cow's milk

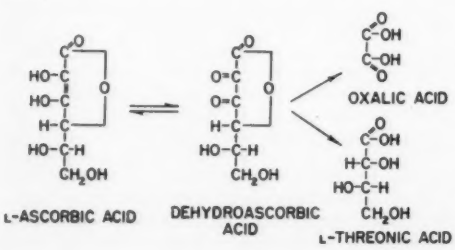
Vitamin	Per quart of milk	Per cent of daily requirement[c]
"A"[a]	1,870 I.U.	37
"D"[b]	400 U.S.P. units	100
Thiamine	0.40 mg.	38
Riboflavin	1.47 mg.	92
Nicotinic acid	0.80 mg.	5.3
Ascorbic acid	15 mg.	20

[a] Total vitamin A activity including carotene.
[b] Fortified milk.
[c] As taken from the National Research Council Publication 302, 1953. Recommended Dietary Allowances (Reference *60* for an average man).

milk is an excellent source of riboflavin, although the photochemical destruction of this vitamin is a problem of some practical importance *(75)*. The need to prevent exposure of milk to sunlight is, in part, due to the sensitivity of riboflavin. Under normal circumstances of handling milk the loss is not great, however. It is also evident that milk is an important source of thiamine.

The complexity of the interrelationships of food constituents is illustrated by the nicotinic acid content of milk. Although it is well known that milk is a pellagra-preventive food, a chemical analysis for nicotinic acid considered in relation to recommended daily intake suggests a food low in nicotinic acid. The explanation for this apparent discrepancy, aside from the general philosophy that the recommended allowances tend to be on the liberal side, rests on the fact that milk protein is an excellent source of tryptophane. Well documented experiments have established the metabolic conversion of tryptophane to nicotinic acid *(74)*. The implication is that a chemical analysis of a food for a constituent, although of value, is not always definitive except as considered with respect to other related metabolites.

Fresh milk as it is secreted is a good source of vitamin C, but the sensitivity of this vitamin to oxidation, especially in the presence of light or oxygen and metals, makes it difficult to process the milk and still retain all the ascorbic acid. Therefore, market milk at its best usually has lost some of its original antiscorbutic activity.



The products of oxidation of ascorbic acid are first dehydroascorbic acid, then rupture of a carbon to carbon bond to give oxalic acid and L-threonic acid *(76)*. The oxidation is reversible until it proceeds beyond the stage of dehydroascorbic acid. If the method of estimation does not include the dehydro form, the antiscorbutic properties, or the vitamin C potency, of the milk will be underestimated.

The importance of the other vitamins in human nutrition has not been sufficiently well established to warrant recommendations by the National Research Council. As one might expect, they all occur in milk at such levels that it is difficult to initiate a vitamin deficiency when milk is consumed. Orotic acid has recently been isolated from milk *(31)*. Its structure suggests an interesting relation to pyrimidine biosynthesis although it has not been implicated as a vitamin for humans. There is some evidence that milk products contain other growth-promoting factors for chicks, but validity of claims must await the isolation and identification of the compounds.

Salts

Milk is the best common source of calcium and phosphorus (Table 5). One quart supplies

TABLE 5
Salts in milk[a]

Ca	P	K	Na	Mg	Cl	Citrate	Fe	Cu
(g. per quart)							*(mg. per quart)*	
1.17	0.90	1.30	0.54	0.11	0.97	2.10	0.9	0.3

[a] Reference 58.

84% of the daily recommended allowance of calcium for growing boys and girls at the period of their highest requirement *(60)*. This amount of milk supplies the full recommended allowance for all other age classes except for women during pregnancy and lactation, when additional allowances for calcium should be made.

Insufficient data are available to permit recommendations for phosphorus intake. Most diets which meet calcium and protein requirements are also adequate in phosphorus *(60)*. The ratio of calcium to phosphorus is important for proper utilization of these nutrients. It is noteworthy that the milk calcium to phosphorus ratio of 1:1.3 is regarded as ideal by nutritionists. Appreciable variations from this ratio lead to excessive excretion losses.

The interrelationships of dietary constituents are further evident with lactose, vitamin D, and calcium. The presence of lactose in the diet assures favorable conditions for absorption of calcium *(54)*. The need for an adequate intake of vitamin D for the efficient utilization of calcium and phosphorus is also well documented *(77)*.

The National Research Council recommendations for iron range from 8 to 12 mg. per day and those for copper about one-tenth that of iron. The newborn mammal usually has liver stores of these elements to supplement the period of nursing. Prolonged consumption of milk as the sole food can lead to an anemia correctable by supplementation with copper and iron *(86)*.

Deficiencies of the other mineral elements are not ordinarily encountered in humans. There is insufficient evidence to permit recommendations, but the suggestion is that the proportions found in milk are highly satisfactory. The cations of milk are largely chloride and citrate. Their function in nutrition has also not been established.

Conclusions

The purpose for which milk is produced by mammals requires it to be a well balanced and almost nutritionally complete food. On the basis of present evidence the special value of milk in the diet can be attributed to its balance of nutrients, abundance of high quality protein, plentiful supply of minerals and vitamins, and highly acceptable bland flavor. Because of these properties, milk is particularly valuable in diets for growth and during pregnancy and lactation and in diets requiring a high ratio of protein and other nutrients to calories (reducing diets).

The competitive nature of the markets requires the dairy industry to take every measure to insure preservation of flavor and nutrients in products delivered to the consumer. The dairy industry should also appreciate the limitations of its products and promote only the facts to insure against misunderstanding. Galactosemia, a comparatively rare disease of humans, is discussed as an example of such a limitation.

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Dairy Production Research in the United States Department of Agriculture

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Research, demonstration, and the collection and dissemination of information useful to the dairy farmer have been carried on in the United States Department of Agriculture for about 70 years. The first work was done by the Bureau of Animal Industry. During the last quarter of the 19th century the dairy industry had grown to such prominence in the agricultural economy that Congress enacted legislation to establish a special Dairy Division in the Bureau of Animal Industry to pursue research and education for the benefit of that industry.

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While the dairy industry was making rapid growth at this time, it was at a low state of efficiency. In 1890 there were about 15 million cows kept for milk on farms. Their average production was about 2,700 lb. of milk and 115 lb. of butterfat. Knowledge of feeding and the production of efficient, low-cost feed supplies was limited. There was no testing program to guide farmers in their breeding and feeding operations or in culling poor cows from their herds. Methods of producing milk of high sanitary quality were inadequate.

Departmental Organizations for Dairy Production Research—1895 to 1956

The Dairy Division began functioning July 1, 1895. During the formative years the production work of the new Division developed along several lines, namely, breeding, feeding, and management; animal nutrition; physiology; milk secretion; milk quality improvement; and cow testing.

As the work of the Dairy Division grew, it became increasingly popular in the industry. As early as 1912 various dairy groups began asking for an independent bureau for dairy work. In 1924 Congress passed a law that established the Bureau of Dairying and in 1926 enacted legislation changing the name to the Bureau of Dairy Industry.

By that time the major emphasis was on research and less attention was devoted to introduction and extension. In 1929 three major divisions were pursuing production research in the Bureau: the Division of Dairy Research Laboratories, which conducted work on dairy cattle nutrition, physiology, and milk composition; the Division of Dairy Cattle Breeding, Feeding, and Management, which included the dairy cattle breeding investigations, the field station work, and the Beltsville station feeding and management research; and the Division of Dairy Herd Improvement Investigations, which included the investigational work relating to cow testing. In 1937 the Division of Nutrition and Physiology was organized by separating the nutrition and physiology work from the Division of Dairy Research Laboratories and combining with it the physiological work that was being done in the Division of Breeding, Feeding, and Management. In 1946 the feeding research at Beltsville was transferred from the Division of Breeding, Feeding, and Management to the Division of Nutrition and Physiology.

On January 2, 1954, as a part of the reorganization of the U. S. Department of Agriculture accomplished by Secretary E. T. Benson under authority granted him by Congress in Reorganization Plan No. 2 of 1953, the Bureau of Dairy Industry was abolished and the production research was established in the Dairy Husbandry Research Branch.

The objectives of the Branch program continue to be the investigation, demonstration, and dissemination of useful information to advance the dairy farming industry. The present research staff numbers about 60 technically trained scientists.

The men who have served as chiefs of the Division, Bureau, and Branch and who have been responsible for the dairy production research in the Department from 1895 to the present, and their periods of service, are shown in Table 1.

Research and Demonstration Facilities

The headquarters of the dairy production work from 1895 to 1954 was in the U. S. Department of Agriculture building in Washington, D. C., and since 1954 at the Agricultural Research Center, Beltsville, Md.

When the Dairy Division was first formed, it had no research facilities, and much of its investigational work was done in laboratories provided by the Biochemic Division of the Bureau of Animal Industry. In 1902 the first laboratory facilities were provided in Washington, D. C., for the work of the Dairy Research Laboratories. The facilities used in dairy herd improvement investigations were devel-

TABLE 1

Name of chief	Period of service	Organization name
Major H.E. Alvord	July 1, 1895, to Oct. 1, 1904	Dairy Division, Bureau of Animal Industry
Mr. H. E. Webster	July 1, 1905, to Jan. 1, 1909	Dairy Division, Bureau of Animal Industry
Mr. B. H. Rawl	July 1, 1909, to Feb. 15, 1921	Dairy Division, Bureau of Animal Industry
Dr. C. W. Larson	Feb. 15, 1921, to July 1, 1924	Dairy Division, Bureau of Animal Industry
Dr. C. W. Larson	July 1, 1924, to July 1, 1926	Bureau of Dairying
Dr. C. W. Larson	July 1, 1926, to Jan. 1, 1928	Bureau of Dairy Industry
Dr. L. A. Rogers[1]	Jan. 1, 1928, to Sept. 1, 1928	Bureau of Dairy Industry
Dr. O. E. Reed	Sept. 1, 1928, to Jan. 2, 1954	Bureau of Dairy Industry
Dr. R. E. Hodgson	Jan. 2, 1954, to present	Dairy Husbandry Research Branch, ARS

[1] Served as acting chief.

oped in Washington, where they are located at present.

Beltsville Dairy Station. As the production research programs developed, the need for extensive laboratory and farm facilities became increasingly apparent. In 1910 the Dairy Division acquired a tract of 189 acres of land in nearby Maryland, together with a few usable buildings. This was the beginning of the Beltsville Dairy Research Station. In later years additional land was added to the station until now about 600 acres are available. Experimental barns and other special buildings have been added so that facilities are available now for some 700 to 800 head of cattle. Chemical, bacteriological, physiological, and other types of laboratories are available for the use of about 40 scientists working on various breeding, feeding, physiological, nutritional, and management projects concerned with dairy production.

Departmental Field Dairy Research and Demonstration Stations. In order to meet the ever increasing need for information in the different regions, additional facilities were required. Congress authorized a number of dairy field stations in the less well developed dairy states to enable the Department to better serve these areas. The research at these field stations was planned to produce information especially useful to those areas to improve dairy farming. The number of stations authorized, their location, size, and present status are shown in Table 2.

FIG. 1. Aerial view of Bureau of Dairy Industry buildings at the Beltsville Research Center, Beltsville, Maryland.

Cooperative state experiment station research. From the beginning of its work the Dairy Division developed cooperative relations with state experiment stations to carry on some of its research. This policy has been followed to an increasing extent in the following years. In this cooperative work the states generally have provided the facilities. In addition, formal cooperative relations were developed with all of the states dealing with the dairy herd improvement association and sire-proving investigations.

Milk quality work. Early work of the Dairy Division concerned itself with investigations to improve the quality of milk. A lot of this early work dealt with surveys of farms and milk supplies. A bulletin issued in 1897 gave 50 rules for dairy farmers, mainly directed toward producing clean milk. In 1910 a score card for rating dairy farms was developed by Division workers in cooperation with committees of the American Dairy Science Association. This score card is the progenitor of the score card in use today.

From 1912 to 1925 a considerable amount of research was conducted by Ernest Kelly and C. J. Babcock on the causes of abnormal flavors of milk. A special barn was constructed at Beltsville for this work. The effects of unclean vs. clean conditions, of oats, silage, garlic, beet tops, grass silage, and other feeds and materials used in the barn on the flavor and odor of milk were studied, and the results and recommendations were made available in several department publications. Since this extensive research, little has been done on feed flavors except for studying the effect of various silages, especially grass silage, on the flavor and odor of milk.

Dairy herd improvement investigations. The Dairy Division began investigational work to develop the cow testing program (later called the dairy-herd-improvement association pro-

TABLE 2

Department of Agriculture Dairy Field Stations

Location	Date started	Date discontinued	Size of station	Breeds of cattle	Size of herd	Remarks
			Acres			
Jeanerette, La.	1914	——	200	Jersey, Red Sindhi & crossbreds	150	Station cooperative with Louisiana Agricultural Experiment Station since 1914. Research program jointly planned and conducted since 1947.
Huntley, Mont.	1916	——	100	Holstein-Friesian	150	Research program became cooperative with Montana Agricultural Experiment Station in 1946. Station property turned over to Montana by Congressional Act in 1949.
Ardmore, S. D.	1916	1932	250	Holstein-Friesian	40	Station closed because of lack of funds.
Woodward, Okla.	1920	1952	150	Holstein-Friesian	75	Station cooperative with Oklahoma Agricultural Experiment Station since 1921. Closed because of lack of funds.
Mandan, N.D.	1927	1955	627	Holstein-Friesian	60	Station closed because of lack of funds.
Pontiac, S. C.	1928	1947	200	Guernsey	100	Station cooperative with S. C. Agricultural Experiment Station. Closed due to lack of funds. Herd transferred to S. C. Agricultural Experiment Station for cooperative breeding project at Clemson, S. C.
Lewisburg, Tenn.	1928	——	500	Jersey	200	Station and program jointly planned and conducted with Tennessee Agricultural Experiment Station since 1947.
Hannibal, Mo.	1931	1945	150	Jersey	75	Station facilities and part of herd furnished by Missouri Agricultural Experiment Station. Program jointly planned and conducted. Closed due to lack of funds.
Willard, N. C.	1938	——	125	Jersey	75	Station facilities and part of herd provided by North Carolina Department of Agriculture and North Carolina Agricultural Experiment Station. Program jointly planned and conducted with North Carolina Agricultural Experiment Station.
Puyallup, Wash.	1930	1942	100	Holstein-Friesian	100	Station facilities and herd provided by Western Washington Experiment Station. Program jointly planned and conducted with Washington Agricultural Experiment Station. Discontinued because of lack of funds.
Logan, Utah	1930	1941	125	Holstein-Friesian	100	Station facilities and herd provided by Utah Agricultural Experiment Station. Program jointly planned and conducted. Discontinued because of lack of funds.

gram) in 1908. Helmer Rabild, the man who organized the first association in Michigan in 1905, was employed for this work. The development of cow testing involved work in farmers' herds in the states and because of this it was done cooperatively with state extension specialists. The first need was the development of uniform organizational procedures and suitable forms for recording the data needed on the production and related items concerning each individual cow in a herd, which would be acceptable to all states. Considerable investigational work was done by Rabild and later by his successors, J. C. McDowell and J. F. Kendrick, to bring this about. The testing program soon developed into a nation-wide herd improvement effort.

The departmental dairy workers, in cooperation with the state specialists and the American Dairy Science Association, assumed the responsibility of a coordinating agency for the program. The Division, and later the Bureau, served as a central repository for the data that were produced and sent to it from all the co-

operating states. Annual summaries were made of these data and the results were made available to the public. The data also were used by researchers to investigate trends and progress in average production of association cows and herds and to develop new information, procedures, and techniques to advance the testing program and to improve dairy farming generally.

After 50 years the testing association has grown to where on January 1, 1955, there were 2,288 associations with 41,240 herds consisting of 1,333,866 cows on the standard plan of testing. This represents about 5½% of the milk cow population.

As early as 1916, reference was made in a Division publication to investigations on using cow-testing association records to compare the production of daughters and their dams for the purpose of indicating the transmitting ability of bulls. In the following years the Division, and later the Bureau, began making daughter and dam comparisons for proving bulls and issuing listings of sire provings. In the early thirties, as a result of extensive study and the adoption of modern calculating machines, plans were begun to develop a nation-wide cooperative sire-proving program. By this time suitable forms and a system of ear tagging cows for identification purposes had been developed so that a complete file of all production records sent in to the Bureau could be kept for use in developing sire provings. A nation-wide cooperative sire-proving program was initiated in 1937. That year the publishing of an annual DHIA proved-sire list was begun. More than 50,000 sires have been proved in this program to date.

Dairy cattle breeding research. The first dairy cattle breeding research in the Department was begun by T. E. Woodward at Beltsville in 1912, at which time 16 cows of mixed breeding, 1 purebred Holstein bull, and 1 Guernsey bull were purchased. Two inbred lines were developed, one from the Holstein sire and his male descendants, and one from the Guernsey sire. The purpose of the research at that time was to see whether a small herd owner might safely breed a bull back to his daughters, and thus avoid having to replace him with another bull. The results published in 1933 and in 1946 indicated that if a bull carried no lethal factors or factors for malformed calves he could be safely bred back to his daughters but that generally farmers should not practice inbreeding of their dairy cattle. The possible hazards from intensive inbreeding were pointed out.

In 1917, a more comprehensive breeding experiment was begun by R. R. Graves and later continued by M. H. Fohrman. This work was to involve a large number of animals over a long period of years, which would be necessary in a breeding experiment of this nature with large animals. Both the Holstein-Friesian and Jersey breeds were used in these investigations. There were several phases to these breeding investigations. Because of the early interest in the proved sire, this research was planned to demonstrate the value of the continuous use of meritoriously proved sires for improving the production of the female herd. In addition, inbreeding, linebreeding, and outcrossing systems of breeding were investigated. With the Jerseys, the then popular family breeding system, a form of linebreeding, also was tested. These experiments were the result of a long-felt need for greater knowledge of the fundamental principles of breeding dairy cattle. When these projects were laid out, the planners recognized the important influence that changing environmental conditions might have on production records, so from the beginning all reasonable efforts were made to maintain the same feeding and management conditions for each generation of animals on the experiments.

As the several dairy field station herds were established, they were utilized in an extension of the Beltsville breeding investigations, particularly those relating to the proved sire. In this respect the Beltsville proved sire breeding investigations were replicated in one form or another at each of the field stations.

Progress reports of this breeding research indicate that the continuous use of meritoriously proved sires generation after generation, either with natural or artificial breeding, produced a significant increase in the production ability of the experimental herds of Holsteins and Jerseys and that the variability of production among the daughters of the proved sires used was reduced with succeeding generations. Greater production performance was obtained from outcrossing than from linebreeding or inbreeding. Family breeding in the Jerseys did not yield superior results to outcrossing.

Recognizing that the supply of meritoriously proved sires was very limited, the Bureau started a program of lending to farmers and farmer groups sons of proved sires used in the projects. The loans were made with the agreement that the farmers test their cows and furnish the investigators with production data with which to measure the transmitting ability of these bulls. To date about 1,200 young bulls from Beltsville and the field stations have been on loan to farmers, cooperative bull associations, and artificial breeding associations. More than three-fourths of these bulls have been proved and over three-fourths of the bulls proved sired daughters that on the average were better producers than the daughters' dams when tested under farm conditions.

In 1935 when the value of the production-proved sire was being rather conclusively demonstrated and when the DHIA testing and sire-proving work was well under way, the Bureau, in cooperation with the state colleges, made a comprehensive germ plasm survey of the progress that had been made in college and farmers'

herds toward improving the quality of the dairy cattle. This survey analyzed 1,068 herds representing seven breeds of dairy cattle in 43 states. The results of this study were reported in the 1936 Yearbook of Agriculture and tended to inventory the position and progress that had been made in these herds that had been on a testing program for a number of years.

In 1936 the Bureau imported a herd of 20 heifers and two bulls of the Red Dane breed from Denmark. The purpose was to test the value of this breed of dairy cattle, which had reached such prominence in Denmark, under conditions in the United States. This herd has been maintained and increased through its offspring. At Beltsville it was found that this breed performed favorably but no better than our existing breeds. Through cooperative arrangement with the Michigan State College bulls from this herd were made available to farmers in several localities in Michigan for use in their herds and for proving. This resulted in a group of farmers in that state developing an interest in the breed to the extent that they have organized a breed registry program known as the American Red Danish Cattle Breeders Association.

In 1947 the Beltsville Red Dane herd was moved to Indiana, where it is used in a cooperative breeding research project with the Indiana Agricultural Experiment Station.

As a result of interest in crossbreeding and the development of hybrids in plant and animal species other than dairy cattle, M. H. Fohrman in 1939 initiated investigations to develop information on the value of crossbreeding dairy cattle for commercial purposes. In this research three breeds were used, Holstein, Jersey, and Red Dane. A breed rotation pattern was used so that each project animal was bred to a purebred, meritoriously proved bull. The results of these investigations, published in 1954, suggested that commercial dairymen who are not interested in a particular breed of cattle could enhance the producing ability of their cows by breeding them to the best proved bull available, regardless of the breed.

In 1946 the Bureau's breeding research was significantly enlarged by developing projects in cooperation with 10 different state stations. In this research various projects on inbreeding, linebreeding, outerossing, crossbreeding, relation of breeding to composition of milk, and related problems are under study.

Breeding research was undertaken to see what could be done to develop strains of dairy cattle that are better adapted to the more severe climatic conditions in the South. In 1946 two heifers and two bulls of the Red Sindhi breed of Brahmans were introduced from India. These animals formed a foundation for crossbreeding experiments with the Sindhi, Jersey, Holstein, and Brown Swiss. This work is in progress at Beltsville, Jeanerette, La., and at three southern state experiment stations. As a part of the breeding research, physiological and climatological investigations are in progress to study the reaction of the animal to its climatic surroundings and the manner in which it adapts itself to high temperatures and humidity. This basic work involved the development of methods for measuring such animal reactions as body temperature, skin temperature, heat production and dissipation, and moisture loss. This research will enable scientists to more accurately measure climatic stress and the adaptability of animals to hot climates.

Growth, conformation, and anatomy in relation to producing ability. From the beginning of dairy cattle research, Department workers realized the need for information on the rate of growth and development of animals throughout their life. Systematic programs for recording weights and other measurements of animals in the several herds were used. Growth standards have been developed and published from these data. The most recent standards for Holstein and Jersey cows were issued in 1955.

In 1922 W. W. Swett started taking detailed measurements of the external form of cattle at specified ages for the purpose of determining if ways could be found from such data to identify superior or inferior producing animals. The need for culling inferior animals always has been great, and if a simple method could be developed to guide the farmer in selecting such animals at early ages it would greatly reduce the cost of raising herd replacements. Measurements of the size and weight of internal organs of animals killed after their period of usefulness were obtained so that correlations could be made with producing ability. Measurements were also made of the size, shape, capacity, structure, and attachment of the cow's udder.

This kind of research was undertaken in an effort to determine the most desirable size and shape of a cow for the greatest and most efficient performance. From time to time summaries have been published of such findings as the relation of birth weight and weight of calf at various ages to mature weight and production; the embryonic development of the fetus; the early identification of freemartins; the relation of size of cow to production; the relation of size of various glands, such as the thyroid, to production; the knowledge that milk secretion is a continuous process; the structure of the secretory tissue and the circulatory system of the udder; and the rate of release of milk from the udder.

As a part of these studies regular periodic measurements were made of the growth and development of the udder of the growing calf. This, together with postmortem studies of the udders of calves, led to a new understanding of the growth and development of the udder. Measurements taken of the udders of many calves revealed considerable variation in the size at particular ages. Bureau calves were systematically graded on the degree of udder devel-

opment, and these grades later were related to the milk yield of the animal as a cow. Correlations indicated significant relationships, and this led to the idea that a system of grading calves could be developed which would, with some accuracy, identify the future inferior producers, by means of udder palpation, when they are 4 to 6 months of age. Such a system has been developed and was made available in a Department bulletin in 1955. The palpation system presently is being tested out under field conditions, and, if it proves as good in the field as it has at the Beltsville station, farmers will have at their disposal a more accurate method than they now have to cull the prospective low producers from their herds before much cost has gone into their raising.

Reproduction and lactation. Problems relating to efficient reproduction and lactation have long occupied the attention of Departmental dairy scientists. Shortly after the Bureau was organized in 1924 studies were begun by F. W. Miller at Beltsville on factors affecting the breeding efficiency in cows and bulls. Studies were made of the normal and abnormal male and female reproductive tracts. In 1930 the first bovine tubal ovum ever observed was recovered from a cow at Beltsville. This was followed by culture studies of bovine and rabbit ova. By 1935 fertilized rabbit ova were recovered and the early embryonic development was observed. This, together with a picture story of fertilization, gestation, and parturition, was portrayed by cinematographic and motion picture techniques.

Studies on the collecting and on the composition, storage, and keeping quality of semen were begun in 1930. Studies on the rate of semen movement in the female genital tract were reported in 1933, and in 1935 a technique for collecting semen from bulls not able to serve normally was described. At that time shipments of semen were made from Beltsville to field stations for artificial insemination but without success.

About 1935 physiological studies were started by S. R. Hall on the hormones involved in reproduction and lactation, including the pituitary, gonadotropic and lactogenic substances. Excreta of bulls and cows were studied for hormone-like substances. These researches contributed to the early understanding of the role of hormones in reproduction and lactation.

In 1941 studies were begun on the influence of nutrition on the reproductive performance of bulls, and a report appeared in 1946 on the effect of vitamin A deficiency on the development and reproductive performance of bulls.

As purified hormone materials became available, work was taken up by J. F. Sykes in 1945 on the relation of prolactin and other lactogenic hormones to the development and function of the mammary gland. Basic studies were begun on developing improved chemical and biological methods for estimating the content of certain hormones in blood and tissue. Histochemical studies also were begun on the physiological activity of the female reproductive organs.

Since 1946 an expanded research program, in cooperation with five different state experiment stations, has been in progress to develop new information on nutritional and physiological causes of infertility in cows and bulls. This physiological research has contributed, and will continue to contribute, to improving the reproduction and lactation efficiency of dairy cattle.

Milk secretion. Some of the earliest work of the Dairy Division concerned itself with milk secretion. Cooperative work with the Missouri Agricultural Experiment Station between 1905 and 1912 dealt with various aspects of milk secretion, such as the influence of breed, feed, and individuality on the yield and composition of milk. Reports by Eckles and Shaw and others give their findings in several of the early Division publications. These include "Influence of Stage of Lactation on the Composition and Properties of Milk"; "Influence of Breed and Individuality on Composition and Properties of Milk"; "Variations in the Composition and Properties of Milk of Individual Cows"; and "Estimation of Total Solids in Milk by Formula."

Later, in 1915, E. B. Meigs was employed by the Division to study more precisely the actual mechanism of milk secretion. This work was done at Beltsville and concerned itself more with the chemical constituents in feed and blood as precursors of milk constituents. The minerals, calcium and phosphorus, in blood and milk were studied, as were the various amino acid constituents. The work on amino acids led to a better understanding of the precursors of milk protein. Reports by E. B. Meigs and C. A. Cary on the "Influence of Calcium and Phosphorus on Yield of Milk; The Relation Between Diet, Composition of Blood and Secretion of Milk; Calcium and Phosphorus Metabolism in Dairy Cows; The Effect of Water in the Ration on the Composition of Milk"; etc., describe these researches.

Later work on frequency, regularity, and rapidity of milking, the influence of machine and hand milking, and related studies have contributed knowledge to this important subject.

Nutritional requirements of dairy cattle. It was early recognized that to be able to feed cows efficiently one must have a good knowledge of the requirements for the different nutrients for growth, reproduction, and lactation. Work on nutritional requirements began by cooperative studies by H. P. Armsby at the Pennsylvania Agricultural Experiment Station and continued from 1915 to 1922. This work concerned itself with the energy requirements of cattle and a determination of the energy value of feeds. Work begun at Beltsville in

1915 and continuing until about 1945 dealt with the calcium requirements of calves and cows for normal growth, reproduction, and lactation. These researches involved long-time studies with animals during growth and throughout several lactations and have contributed much to our present-day knowledge of the calcium requirements of dairy cattle.

The protein requirements for milk production came under investigation in the late 1920's. Much of this research was directed towards both the level and the amino acid composition of the protein required. Considerable chemical work was done on developing methods for determining amino acids in proteins of feed and milk and in testing out feeds low in certain amino acids. Later, in 1945, a new series of experiments was initiated to study the level of protein. Cows were carried through several lactations on protein levels of 70, 100, and 120% of the Morrison standards. Cows receiving the low level performed as well as those receiving the recommended or more than the recommended amount. This work was pertinent to the then limited protein supply caused by war conditions.

Shortly after vitamin A was discovered, work was begun on determining the needs of this vitamin for the calf and the cow. This was prompted by the fact that some of the experimental animals on calcium requirement and hay-quality feeding experiments were found to be affected with vitamin A deficiency. This was evidenced by failure of the cow to deliver a normal calf at parturition or by giving birth to blind and weak calves. Night blindness in some of these cows also occurred. Systematic studies on the requirements for carotene, the natural source of vitamin A for the cow, resulted in information on the amount of carotene cows need for normal health and reproduction. Likewise, the amount of carotene or vitamin A needed by the calf for normal growth was studied, and information from Bureau laboratories added to the knowledge of this subject. Considerable information was also gained regarding the symptoms and pathology of vitamin A deficiency.

The nutritional requirements of calves for protein, energy, trace minerals, vitamins D and E, and the water-soluble vitamins have been, or presently are being, studied in order to gain a clearer knowledge of the need for these nutrients in the growth of the calf. Much of the current work is being done with synthetic-type diets that have been perfected to a rather high degree of proficiency.

Early work developed information on raising calves with no whole milk and a minimum of skimmilk. These findings were especially important during World War II when milk was in short supply.

Pasture research. Research on more efficient production, management, and utilization of pasture always has been an important part of the experimental program. Improvements in the utilization of this important low-cost feed crop offered one of the best ways of lowering the cost and increasing the efficiency of milk production. Pasture studies have been carried on at Beltsville and at all the field stations. The evaluation of new pasture crops and of crop combinations developed and proposed by agronomy coworkers has been made in each of the regions where field stations are located. Important information has been developed regarding the value of rotational grazing, pasture fertilization, supplemental irrigation; the value of permanent, rotation, and supplementary pasture; the importance of legumes in the pasture mixture; daily rotational grazing; green feeding, etc. Also, important contributions have been made to the development of techniques for experimentally measuring the yield of pasture with dairy cows.

Research on harvesting and utilization of forage. Investigations on harvested forage always have had an important place in the feeding and management research at Beltsville and at each of the field stations. One of the first projects at the Beltsville station was devoted to the making of silage. The first work was on factors affecting the losses, quality, and feeding value of corn silage. Studies were carried on at various times with upright, trench, snow fence, stack, and bunk silos. Extensive feeding experiments were conducted with corn silage as the principal or the entire forage ration. Weights per cubic foot of different kinds of silages stored in silos of different sizes, kinds, and shapes have been determined in order to establish silo capacities.

Early in the 1920's considerable attention was given to making silage from grasses, legumes, and grass-legume mixtures. After extensive tests with various additives, etc., T. E. Woodward and J. B. Shepherd developed and recommended the now popular wilting method of making grass silage. In this work many feeding tests were conducted to evaluate the various experimental silages produced.

In spite of all the work that has been done on making grass silage and the prominence that grass silage is taking on dairy farms at present, a large amount of research is still being done on this problem. Much of the current work is of a basic chemical and bacteriological nature and is designed to give fundamental information to guide practical grass-silage-making procedures.

In the same manner, research on hay as feed for dairy cattle has been a major activity. The relation of quality to feeding value, the conditions that make for good quality hay, the losses due to harvesting and storage, method of curing, etc., have been subjects of investigation.

One of the significant researches in forage was that done by the Bureau under the leader-

ship of J. B. Shepherd and in cooperation with other Departmental Bureaus on the comparative efficiency of four different ways of harvesting and preserving forage. This work was reported in 1954. The results of this study have focused new attention on the need for improving the quality of roughage and on the production of grass silage.

Bureau workers at Beltsville and the field stations have conducted and reported investigations on the feeding of all-forage rations to dairy cattle. The results point up the important contribution that forage can play in the economical production of milk and demonstrated that good cows fed all-forage rations will produce 60 to 70% as much milk as they will on rations including with the forage a normal amount of concentrates. Other work in cooperation with 10 state experiment stations and the Bureau of Agricultural Economics dealt with the feed input–milk output relation in feeding dairy cows. Research is currently in progress on raising herd replacements largely on forage rations.

When it was learned that carotene in the feed was the natural source of vitamin A for the cow, much work was done on determining the carotene content of feeds, especially forages, and on measuring the influence of various factors affecting the carotene content of feeds. The rate of loss of carotene in hay and silage was determined, and the fact that silage making is a good way to preserve carotene for feeding was established.

Another more recent phase of the forage research is the improvement and development of new techniques for evaluating the nutritional value of forage. Recent research on this phase involves the improvement in the procedures for the chemical determination of the nutritive constituents in feeds and improvement and simplification of the methods for determining the digestibility of feeds. Research on determining the net energy value of forages is being revived. Work in this field was originally started by Armsby but fell by the wayside in the early 1920's.

Another phase of forage research is the role of rumen bacteria in the utilization of forage nutrients. Systematic studies of the identification of the rumen microorganisms, their nutritional requirements, and their role in feed utilization by the cow are in progress at the present time.

Research on feed supplements. The value of grain and of grain-and-seed by-products as feed for dairy cattle has been given much attention, especially in the earlier years of the Department's dairy research. The value of grain mixes as supplements to forage and pasture of different qualities, the comparative value of single grains or complex grain mixtures as supplements, the value of southern by-product mixes, and related problems have been investigated. During the years 1945 to 1954 extensive investigations by L. A. Moore and J. W. Thomas of the value of feeding thyroprotein to dairy cows have contributed greatly to our knowledge of this subject. Antibiotics for calves and stilbestrol and other hormone-like materials for cows have been or are being investigated with respect to feeding dairy cattle.

Nutritional value of milk. Shortly after the Bureau of Dairy Industry was established, a unit was set up to study the nutritional value of milk, especially as it is affected by the nutrition of the cow. Some of the first work dealt with the vitamin A content of milk and butter. Research showed how the vitamin A value of milk and butter varied with the carotene received in the feed by the cow and that the cow was very wasteful in the utilization of carotene. It also brought out the importance of preparing forage for winter feeding in such a way that it would have a good carotene content and thus insure a milk supply of high vitamin A value. It also showed the significance of the cow's body reserve of carotene in relation to the vitamin A value of milk.

In 1941, in cooperation with 21 state colleges, a national survey of the vitamin A content of the nation's butter supply was initiated. This was a war-time project and the results that were published in 1945 and 1947 received much attention.

In 1937 this work on milk nutrients revealed the existence of an unidentified nutrient in milk. During succeeding years, studies were made of the physiological effects of the nutrient and its chemical and physical properties. Shortly after the discovery of vitamin B_{12}, Bureau scientists found it to be identical with the nutrient with which they were working. Further research has shown that the B_{12} content of milk is not dependent on the B_{12} in the feed of the cow and that milk and dairy products are good sources of this vitamin.

Research on the nutritional value of butter and butterfat as compared to that of certain vegetable fats and oils was taken up in 1942. Extensive studies have failed to show any superior nutritive value for butter or butterfat when fed in normal amounts with an otherwise nutritionally complete diet.

Miscellaneous investigations. A number of different types of management investigations have been included in the research program from time to time. A study of mastitis, especially the kinds of bacteria causing mastitis, management methods of control, and the treatment of mastitis has been carried on during the past 20 years. The Hotis test for detection of certain mastitic organisms was developed in 1936. The efficiency of various sulfa drugs and antibiotics in treating mastitis infections has been studied and reported on. The effect of the amount of vacuum of milking machines on the incidence of mastitis was reported.

Various methods of housing cattle, including loose housing, have been investigated, especially at the field stations. The first milking parlor was installed at Beltsville in 1928, and much of the pioneer work on this type of milking installation was done there. The effect of water in the ration on the yield and composition of milk received attention. With the introduction of new pesticides for the control of insects, studies were made of the effect of fly sprays on cows and of the incidence of spray residues in milk caused by contamination of the feeds receiving the treatment before harvesting.

Disease research. For more than half a century veterinarians of the Bureau of Animal Industry and, more recently, of the Animal Disease and Parasite Research Branch have carried on a great amount of research on diseases and parasites affecting dairy cattle and other farm livestock. The causes of many diseases have been identified, and the development of methods for their control and eradication is the result of this research. The development of vaccines that build immunity to certain diseases has protected great numbers of cattle.

Department entomologists also have made great contributions to the control of external insects and parasites affecting dairy cattle. Development of new chemical pesticides, followed by their practical use, is doing much to protect the farmers' cows from the ravages of these pests.

Research Roads Ahead

During the life of the American Dairy Science Association, an organization in which most of the Department dairy production research workers have enjoyed a membership, these men have contributed significantly to the knowledge now being used by farmers to improve their methods and practices. Much progress has been made, as indicated by the fact that milk production per cow has increased from 2,400 lb. in 1895 to over 5,500 lb. in 1955. The quality of the milk produced has been greatly improved. This has been accomplished largely as the result of application of knowledge gained through research, which has made possible better breeding, feeding, and management practices.

But the job is far from finished. The average milk yield per cow is still too low. In the future faster progress must be made in order for the dairy farmer to hold or improve his relative position in American agriculture. Much more research is needed to enable him to speed up the rate of improvement in the efficiency of milk production.

Past research endeavor has dealt for the most part with the easy problems. The difficult ones still lie ahead. Because of inadequate techniques and equipment when some of the past research was done, it needs to be done over with better equipment and methods.

More attention needs to be directed to basic research because it is only through this endeavor that "break through" to the unknown can come that will advance our knowledge resulting from both basic and applied research.

In the future the dairy farmer's opportunity lies in improving the efficiency of milk production, the efficiency of transforming energy and other nutrients in crops into milk nutrients. He must develop cows that are more adaptable and efficient in this conversion. More efficient cows must come through breeding, and research must show how this can be done.

Dairy farmers must greatly improve feed supplies and feeding practices to more efficiently furnish cows the necessary materials for the manufacture of milk in large amounts. Emphasis should be placed on better use of pasture and harvested forages, since these are low-cost feeds and are essential crops for good land use. Better criteria are needed to evaluate feeds. It is time to modernize the feed evaluation methods by shifting to net energy values. Research is needed to remove this roadblock in the way to better feeding.

More complete knowledge of the role of rumen microorganisms in the utilization of feed nutrients by the cow will enable the farmer to take advantage of their aid in improving the efficiency of milk production.

Finally, we must learn how to greatly improve the management of dairy cattle so that they can be cared for with greater comfort and with a minimum of labor and investment in housing. The final research objective is to produce the needed information to enable the dairy farmer to obtain the greatest output of milk per cow, per unit of feed input, per acre of land farmed, and per unit of labor expended. This is the objective to which the Department dairy production research workers are dedicated.

Industrial Research — Production

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In scanning back over developments of the past 50 years, it is apparent that dairy farming already had become of age by 1906. It had grown into a major business. In fact, the then Secretary of Agriculture was impressed sufficiently to praise our forefathers of that day for a farm output "so large as to be beyond any rational comprehension." Yet, today's farm production is virtually double that of a half century earlier.

H. E. Bechtel

Approximately 18.1 million cows produced 63.7 billion pounds of milk on our nation's dairy farms in 1906. Over the ensuing half century, total milk production gradually increased until it reached the present annual estimate of 123.5 billion pounds. This 94% increase in milk output was accomplished by a diminishing number of farmers, and by only about a 34% build-up in population of milk cows—which today have an annual average of about 5500 lb. of milk per cow, or close to 50% more than the average in this country 50 years ago. Moreover, cash farm income from milk herds now totals approximately 5.56 billion dollars, with the milk alone (excluding animals themselves from milk herds) having a retail value of about 8 billion dollars annually. In fact, milk and its products now comprise about 17% of the food purchased annually by American consumers.

What accounts for this unprecedented growth of the dairy production industry? Where is credit due? How long can the average cow continue to show a milk production increase of about 0.85% per year? How much can dairy farmers increase their over-all efficiency? Who is most likely to contribute significantly to the dairy production advances of the next 50 years? What are some of the important dairy production trends—evident, and in prospect? These are among the many questions that logically arise since "each day is a scholar of yesterday," and the real merit in considering accomplishments of the past lies in their use for springboarding more effectively into the future.

Research—the Expanding Resource

Research has been defined as an organized campaign against the unknown. It has opened up widening and endless frontiers. Its importance in agriculture and food production has increased remarkably in modern times. Today, it is not uncommon to regard research as a fifth fundamental resource—along with soil, water, air, and the sun. Research and developmental accomplishments alone account for much of the growth in dairying over the past half century.

This has truly been an age of research—particularly, and in some respects unfortunately, an age of applied research. No nation equals the United States in percentage of national income used for research and development. This in itself may be the most important single reason for the remarkable economic advances and increased productivity in the United States. Research expenditures have increased at virtually an exponential rate for more than the past quarter century, and it is authoritatively predicted that continued economic growth will depend on further steady increases in research expenditures and accomplishments. Current estimates show that at least 4 to 5 billion dollars were spent for research in this country in 1955. This is reputed to be as much as was spent for research in our country for the entire period from 1776 through 1933. Government-sponsored research has been a major factor in recent years. However, a recent survey reveals that private industry in the United States has been conducting much more research than previously expected, with some 554,000 scientists in its employ in 1953 when 2.5 billion dollars were expended by industry for non-government research. Some of the principal effects of this research are yet to be realized since there is normally a 5- to 10-year lag between the uncovering of new research information and its commercial application. The total effects of research often accrue over a much longer period of time, with returns of 100 to 200% a year on the initial research investment. Over the past half century, economic growth has averaged a 3% gain per year, with research and developmental work showing an average increase of 10% per year. Projections, based on an interlinkage of these averages and past trends, foretell total research expenditures in this country of considerably more than 5 billion dollars within the next few years.

Research has changed dairy production practices since 1906, just as it has influenced other major businesses in this country. In this, industrial research has played a major role—through industry's own research departments and through the sponsorship of research at the university and state experiment station level. No one has ever attempted to summarize these countless developments in a master reference, and they cannot be chronicled here. However, the results are evident virtually everywhere.

Witness, for example, the developments in such fields as dairy farm mechanization, cleansing agents, insecticides, manufactured feeds, infectious disease prevention and control, urea and other synthetics for feeding and for the control of conditions such as ketosis and milk fever, antibiotics, hybrid corn, artificial insemination, dairy farm building designs and construction, forage handling and preservation, and many others with direct or indirect impact on dairy production practices. Without the impetus of industrial research, progress in all these fields would have been delayed—and many of the improved dairy production practices, adopted between 1906 and 1956, would have been impossible. At the same time, industry's success during this period stemmed in no small part from its ability to establish and to expand effective working relations with researchers in kindred industries—and with researchers at the experiment station level, so that all could work as a team in developing new research facts and in better paving the way for the commercial application of these facts in industry.

Manufactured Feeds

Nowhere in the entire field of livestock production has industrial research played a more prominent role during the past 50 years than in the development of manufactured feeds. Dairy production has shared in this progress, though recent developments have been noteworthy also in the fields of poultry and swine nutrition.

In 1906, the feeding of dairy cattle was an art virtually without science. Scientists and stockmen had only begun to recognize the need for protein supplements in livestock rations. Mill waste from the manufacture of starch and corn syrup was no longer being poured into the Hamburg Canal in Buffalo, but dry corn gluten feed was only beginning to gain acceptance for use in a few newly devised ready-mixed dairy rations. Representatives of the cottonseed industry were obliged at that time to publicize cottonseed meal in an effort to overcome farmer complaints involving dairy rations that contained poor quality hay; ultimately, the state experiment stations came to the aid of the cottonseed producers by demonstrating excellent results when the ingredient was fed properly. Receipts of the first carload of dried beet pulp only 3 years earlier met with much merchant and farmer indifference, plus semi-official doubts on the part of experiment station workers, but, by 1906, the use of this feed had begun to take hold. The idea of industrial experimentation on the feeding of farm animals was devised in 1910; this led in 1912 to the establishment of Larro Research Farm—as the first, and now the largest, research institution of its kind in the United States. Packing house by-products, dried buttermilk, linseed meal, and fish meal were among the ingredients introduced in those earlier years by the feed industry for livestock feeding. In 1922, the first soybeans were processed, and soybean acreage by 1928 had increased to a major crop. Meanwhile, soybean oil meal has gradually developed into one of the most widely used proteins in manufactured feeds today.

From almost the very beginning of the feed industry in this country, feed manufacturers have been concerned with the application of information developed by state experiment stations and other research workers. Gradually, the need became more urgent to acquire new information more rapidly and to apply it with greater dispatch in the formulation, production, and sale of manufactured feeds. For this reason, an increasing number of feed manufacturers established their own research facilities for animal feeding and laboratory control and for more effective promotion of their branded products on a factual basis.

Starting almost from scratch during the past 50 years, the production of dairy and all other manufactured feeds now is a 4 billion dollar business. As such, it ranks ninth among all United States manufacturing industries—after steel, petroleum, automobiles, meat packing, paper, lumber, bakery products, and primary metal products. Of the current production estimated at close to 35 million tons of formula feeds annually, dairy feeds comprise about 19% as compared with 60% for poultry, 11% for swine, 6% for beef cattle and sheep, and 4% for miscellaneous purposes.

Allied Suppliers in the Dairy Feed Industry

Micro-nutrients, drugs, and other additives—though used in relatively low percentages—account for many of the major advances in the formulation of modern feeds for dairy cattle of various ages. In this field, the allied-industry suppliers have been leaders in original research, in cooperative research, in the commercial production of new additives, and in working with feed manufacturers in adapting the use of these new products to practical field conditions.

Industry has demonstrated its ability to follow new discoveries in this field with the production and marketing of new products of proven safety and efficacy, suitable for use under practical field conditions. Thus, vitamin D has ceased to be a major problem in spite of season or ration peculiarities because it is available in carefully standardized form at a cost in keeping with modern manufacturing know-how. Vitamin A supplements no longer present a serious storage problem because stabilized A preparations have been developed by industry suppliers to a point where they are economically superior to less stable forms of this vitamin. Cobalt, iodine, and other trace minerals are procurable in nutritionally satis-

factory forms on a routine basis. Through industry cooperation, phosphorus supplements are available with a maximum fluorine guarantee—thus safeguarding dairy animals from an element with undesirable effects that were understood only after experiment station research conducted some 25 years ago.

Natural feed proteins long have been in limited supply. Industry is making nonprotein urea nitrogen available in increasing quantities as a protein extender in ruminant rations for dairy cattle—in addition to other uses. Recent estimates indicate the existence of a total capacity of about 500,000 tons of urea now, as compared with a previous estimated annual rate of only 150,000 tons.

Interest in antibiotics for livestock, including dairy animals, stems largely, if not entirely, from industrial research on vitamin B_{12} production—and observations in early 1949 that certain growth responses in chicks exceeded what would be expected from the vitamin B_{12} level in the feed supplement obtained from a fermentation product of *Streptomyces aureofaciens*. This set loose a flood of new research leading to a steady increase in use of growth-stimulating antibiotics—chiefly penicillin, chlortetracycline (aureomycin), oxytetracycline (terramycin), and bacitracin. Some 490,000 lb. of these drugs were used in feeds in 1954, and they now outsell even the vitamins in the field of medicinal products. Mortality from pneumonia-like disorders and enteric diseases has been reduced substantially in dairy calves through the use of antibiotics, particularly chlortetracycline, when fed during the first 12 to 16 weeks at 15 to 20 mg. daily per 100 lb. of body weight; although considerably more research is needed on oxytetracycline, any early growth advantage from either antibiotic seems to be dissipated later in the growing period. Joint research on the part of investigators in educational institutions, government laboratories, hospitals, and private groups has been particularly effective in the antibiotic field—with a rapid exploitation of the resulting fundamental knowledge which has created a bottleneck in new basic know-how for commercial application. Microbiological procedures are proving more rapid and accurate than animal growth tests in industrial laboratories, where research teams are busily studying basic requirements of bacteria and protozoa.

Ketosis prevention and treatment in dairy cows is being accomplished in part by the feeding of salts of short-chain organic acids, particularly sodium propionate. For prevention, ¼ lb. of the propionate is recommended daily per cow, starting at parturition and continuing for 6 weeks. For treatment, ¼ to ½ lb. is recommended per day per animal for about 10 days. This compound is somewhat distasteful to cattle and is best fed in amounts not exceeding ⅛ lb. at a time and preferably in a pelletted feed or in combination with some material that will enhance the palatability of the mixture.

Phenothiazine medication of feeds has been receiving some attention recently to combat worm infestations in cattle.

Other Uses of Drugs, Chemicals, and Biologics in Dairy Production

Industrial research has had a major hand in making certain drugs, pharmaceuticals, and biologicals available as aids in bringing about more efficient dairy production during the past 50 years. Some of these are relatively new. Others are so commonplace as to be taken for granted today. Some of these are as follows:

1. Calcium gluconate, and related compounds, for the intravenous treatment of milk fever. Lately, high-level feeding of vitamin D has been advocated as a preventative, but certain economic and potential cow-health hazards have delayed its commercial application. Meanwhile, as a result of limited research, low-calcium high-phosphorus dairy rations are being scrutinized from the standpoint of milk fever prevention.
2. Improved serologic procedures for brucellosis diagnosis.
3. Serums and vaccines for more effective immunization and treatment of specific diseases.
4. Adrenal cortical and pituitary hormone preparations for ketosis treatment.
5. Thyroprotein stimulation of milk secretion.
6. Sodium metabisulfite and sulfur dioxide as silage preservatives.
7. Antibiotic ointments and other preparations for such diverse uses as treating mastitis, preserving semen, and combating genital infections.
8. Methoxychlor for direct and regular application to lactating dairy cows, for the control of horse flies, horn flies, stable flies, and cattle lice—and, when formulated with glycol fly repellant, for the superior control of the above species and horse flies. This insecticide also is advocated on forage crops, such as alfalfa, up to 7 days before harvest or grazing, for the control of alfalfa leafhopper and alfalfa caterpillars. Methoxychlor was found to be only 1/24th as toxic as DDT, with little or no tendency to be stored in body fat or to be secreted in milk. If desired, methoxychlor, because of its low toxicity, can be applied safely in dry form.
9. Equipment cleansing and sanitizing agents, together with the newer techniques of cleaning pipelines in place.

Industry's Part in Crop and Livestock Improvement

Improved crop varieties afford the modern dairy farmer one of his most important means of helping provide minimum-cost feeds for his dairy herd. Much fundamental research, often at the experiment station level, preceded each new development in this field. However, the seed companies and farmer-seedsmen then took over in making seed available for commercial

use. Corn hybrids are among the best examples of the vital part which aggressive, capable, and efficient business groups have played in translating research into practical dairy farm results. Each new year is accompanied by the latest recommendations on crop varieties best adapted to particular soil and geographic areas.

Dairy cattle improvement received its biggest stimulus with the introduction of artificial insemination on an organized basis in the United States in 1939. Private industry has shared with college-sponsored groups in developing artificial insemination into a multi-million dollar business that includes between 23 and 24% of all the dairy cattle in the country. Approximately 5.15 million dairy cows were bred artificially in 1954 and an additional 4 to 5% gain is believed to have been made in 1955, with the use of between 2,500 and 3,000 sires, of which about 37% were classed as proven bulls. The entry of privately owned organizations into the business has resulted in an increasing use of progeny-tested sires and has accelerated the freezing of semen and the use of antibiotics for superior semen quality. Today, about 28% of all dairy cows being bred artificially are being inseminated with semen from some 16 commercial organizations, and one of these accounts for almost half of all the inseminations handled by these organizations. Artificial breeding is generally regarded as one of the greatest single influences for dairy herd improvement during the past 50 years, and its influence is expected to spread even further in the years ahead. Denmark, where artificial insemination has been used longer than in the United States, now breeds more than half its cattle this way. Modern methods of artificial breeding make it possible to use semen more efficiently so that an outstanding bull producing a trillion sperms annually is potentially capable of siring as many as 100,000 calves in one year.

Mechanization and Automation

Mechanization of all types of farms has been proceeding continually during the past 50 years, and at an accelerated pace since about 1940. The shift from muscle to crude mechanical power, and then to improved machines, is strikingly revealed by a comparison of illustrations and reports in farm papers and textbooks of a half century ago with their current counterparts. Industry obviously played a major part in bringing about these changes in dairy production methods.

Effective use of supplies and equipment is one vital measure of a dairy farmer's managerial skill and ability. To name a few significant changes—the butter worker, butter printer, and cream separator of 1906 may have been improved slightly in the years immediately thereafter, but today they are farm equipment of the past. The ice houses of an earlier day were displaced by can-coolers, and now milk cans are obsolescent in an increasing number of major milk sheds where industry is making available comparatively expensive but labor-saving bulk milk tanks. Pipeline milking and in-place cleaning, though relatively new and costly, are well adapted to the new bulk tank installation. The loafing-shed, milking-parlor system of herd management is enabling more and more dairy farmers to reduce stabling expense and labor costs. Automatic gutter cleaners, designed for trouble-free operation, make for less chore drudgery and eliminate 80% of the time required to clean a barn by shovel and wheelbarrow, or up to 60% of the time to clean out the stable when using a litter carrier. Frozen silage can be handled readily, daily climbing hazards eliminated, and a half hour's work saved daily in a 48-cow dairy by installing a good portable, automatic silo unloader. Once-a-day-feeding of the herd is only one of many other changes that can be made in chore practices to reduce operating costs without loss in herd performance.

Dairy farm mechanization was not enough to assure success during the past 50 years. Thus, cost-conscious industries, desirous of retaining their customers by helping them operate at a continuing profit, have exerted more and more pressure on dairy farmers to set up adequate operating records. Activities along these lines were aided immeasurably by the cow testing association movement launched in Michigan in 1906 and now common throughout the nation. With such records as a starting point, it became possible in succeeding years for industry to establish detailed methods for auditing the performance of individual dairy herds and for analyzing the production of individual cows by a study of their lactation graphs. The maintenance and use of adequate operating records is essential in any war on dairy farming costs, just as in any other type of business.

Widely quoted USDA figures indicate that, in spite of progress during the past half-century, about 62 man-hours still are required per $100 of gross sales to take care of dairy cattle —compared to 45 hours for farm chickens, 27 for sheep, 24 for turkeys, 16 for hogs, 16 for beef cattle, and 12 for broilers. This apparent disparity in dairy production efficiency can become more evident as industry in general gravitates toward increased mechanization and the use of improved technological advances more popularly labeled as automation.

Shift to Simpler Dairy Farm Buildings

Stanchions or stall barns, so common during the past 50 years, became recognized as needlessly expensive to build and to operate. Industrial concerns, along with many of the state experiment stations, took an active part in recent years in developing better building designs for the dairy farmer. As a result, any interested dairyman can turn to a number of

good sources today for data on basic housing requirements of dairy cattle and for building ideas aimed at efficient chore routes, minimum housing, adequate feeding areas, convenient feed storage, modern milk handling, and good over-all farm layout. Industry also has developed more extensive information than ever before on the different types of construction materials. However, know-how on the ventilation of dairy farm buildings has been relatively limited and seemingly still partly a matter of trial and error for each particular building, owing to variations in local conditions.

Over-All Look at Industrial Research in Dairy Production

Industrial research in the field of dairy production made noticeable contributions in the past 50 years along basic, as well as applied, lines. Accomplishments in the discovery and use of vitamin preparations, antibiotics, and other additives stand as unique and new in their field. In applied research, industry was successful over the past 50 years in building manufactured feeds into an important business, in developing many new seed varieties to the commercial stage, in making a successful and progressive business out of the practice of breeding dairy cows by artificial insemination, and in translating numerous other inventions and discoveries into products that found a useful place in the hands of the efficient dairy farmer.

The history of accomplishment during the past half century in the field of dairy production research is heavily interspersed with the names of industrial concerns and their leaders, who have invented new machinery, new products, and new ways of increasing the efficiency of dairy production. With the passing years, more of these accomplishments have resulted from team effort rather than from the work of individual scientists laboring in isolation from others in the same field. This team-approach to research problems is evident in all fields today. It is more than likely that cooperation between scientists at the industrial and experiment station levels will be used with increasing effectiveness in the field of dairy production research during the next half-century.

The Mysteries of the Rumen[1]

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The rumen has long been filled with mystery. About the time the American Dairy Science Association was organized 50 years ago, W. D. Hoard, founder of *Hoard's Dairyman*, stated that the rumen of a cow was the darkest place on earth. Thanks to the shining light of Science, many of these mysteries are being resolved. As a result of the development of the rumen fistula, increased interest has been manifested in the application of new methods and techniques to study rumen activity. The first picture of a rumen fistula cow to appear in the *Journal of Dairy Science* is shown in Figure 1. At the present time, the fistula plugs are made in several designs: plastic plugs with screw-on caps that make removal of all the rumen contents easy and rubber plugs designed to collect gases.

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Fig. 1. First photograph of a rumen fistula cow to appear in the Journal of Dairy Science, 22: 984. 1939. (Ohio Agr. Expt. Sta.).

Duodenal fistulas also offer an opportunity to study rumen balances of constituents that are not absorbed through the walls of the four stomachs (Figure 2). The use of various types of artificial rumens also has made possible the screening of many compounds in the laboratory to study their effect on digestion and synthesis by rumen microbes. The artificial rumen has been very useful in exploring the untapped resources held within the dark recesses of the rumen. Then, too, new chemical and bacteriological techniques are making their contributions to the solution of the mysteries of the rumen.

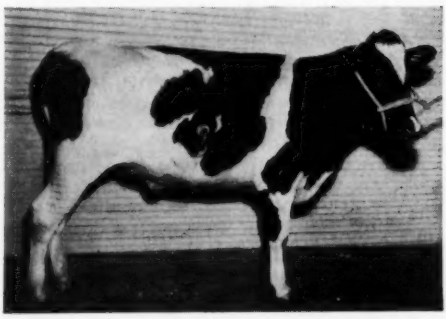

Fig. 2. The use of the duodenal fistula allows a study of the rumen balance of constituents not absorbed through the stomach walls. (Mich. Agr. Expt. Sta.).

The Fermentation Vat

The cow has a true stomach and, in addition, three compartments geared by nature to handle such roughages as pasture grasses, hay, straw, and silage. The first stomach, or rumen, has a very large capacity, whereas the second stomach, or reticulum, is nothing more than a pouch of the rumen. It is referred to as the "hardware" stomach, since heavy objects such as wire, nails, stones, and even gold watches and diamond rings, which are sometimes swallowed, are collected in this pocket. Occasionally pieces of wire or nails pass through the reticulum wall and penetrate the heart to produce what is known as "hardware" disease. The third stomach, or manyplies, contains numerous leaves which provide an absorption area greater than that of the rumen. Other functions of this stomach are not clearly understood.

The rumen and reticulum make up one large compartment, which is commonly referred to as the fermentation vat. This apartment house is the home of many microbes that are busy converting roughage nutrients into soluble forms that the cow can use. In the mature cow, the contents of this vat weigh about 20% as much as the live weight of the cow (240 lb. in a 1,200 lb. cow). In addition to its large size, the location of the fermentation vat at the head of the digestive tract gives the microbes that do the fermenting priority for the soluble carbohydrates, proteins, vitamins, and minerals consumed by the host. Then, too, the products manufactured during fermentation are absorbed more efficiently than is true of simple stomached animals such as the pig and chicken, which have

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal Article No. 1872.

their fermentation vat hooked onto the lower end of the digestive tract. The forward location of the rumen makes possible cud-chewing and the use of saliva to promote increased tempo of fermentation.

Herbage is characterized by a high proportion of celluloses and hemi-celluloses, which can not be digested by the enzymes in the digestive juices of cattle. Considerable amounts of non-protein nitrogen compounds found in roughages are of little value until synthesized into proteins by rumen microorganisms. The feed and water consumed by the mature cow pass directly to the rumen.

Rumen Microbes

The fermentation vat is the home of two classes of microorganisms—bacteria and protozoa. Protozoa are the most primitive members of the animal kingdom. They are microscopic in size but the large protozoa may be 100,000 times as large as some of the bacteria. The function of these animals is not known, although, according to a theory, the protozoa eat the bacteria and convert their contents into nutrients which are available to the cow. The protozoal population in the fermentation vat varies with the amount and kind of feed consumed by the host. Usually the number of the protozoa is about 1,000,000 per cubic centimeter of rumen contents.

Bacteria, on the other hand, belong to the plant kingdom, and the nutrients that they utilize must be in solution to be absorbed. Bacteria are the most important microorganisms in the rumen. Large numbers of different kinds of bacteria are present, several of which have been isolated in pure culture during the past few years. The total number of bacteria present in the rumen ingesta is enormous. Someone has estimated that the number of bacteria in a teaspoonful of rumen contents is greater than the national debt in dollars. The worth-while kinds of bacteria are believed to be the anaerobic (work in the absence of air) and facultative aerobes. Many types of bacteria found in the rumen come from the feed of the cow, and some of these probably do not contribute to her welfare.

In payment of rent for a comfortable home, the rumen bacteria digest the tough carbohydrates in roughages and synthesize high quality protein and valuable vitamins for the cow. As soon as the roughage reaches the rumen, bacteria swarm over it, hunting for cracks and crevices to enter. The cellulose digesters penetrate the fibrous material and the enzymes produced by the bacteria start digesting the feed. Some of the end products of digestion pass through the rumen wall and others are utilized by the bacteria. The food-laden protozoa and bacteria pass on to the true stomach, where most of them are digested and their contents are liberated for further use. From this point on, the enzymes secreted by the cow take over and prepare the microbial material for absorption by the host.

Microbial Digestion of Fiber

More than 50% of the dry matter of most roughage consists of celluloses and hemicelluloses, which are digested by enzymes produced by rumen bacteria. It is believed that these enzymes ride "piggy back" on the bacteria and that direct contact with the forage is essential for digestion. The numerous cavities found in plant material that has been exposed to microbial action are produced by these enzymes.

Probably the most important factor that prevents microbial digestion of celluloses and hemicelluloses is due to the increased deposition of lignin as the plant tissue matures. The lignin and, to a lesser extent, the associated indigestible substances make it impossible for the bacterial enzymes to do an efficient job of digesting the nutrients in mature plants. For instance, the coefficient of digestibility of the fiber in young grass may be 80, compared to 50 when the same grass is in the seed stage. In order to get maximum utilization from roughage crops, it is necessary to harvest them at an earlier stage of maturity. The harvesting of legumes in the early-bloom stage and grasses in the bud-stage is generally recommended.

Short Chained Fatty Acids

Probably the most outstanding rumen research has been concerned with the end products of carbohydrate digestion. It is well recognized that short chained fatty acids, such as acetic, propionic, butyric, isobutyric, caproic, valeric, formic, and probably others, are produced in the rumen. Under normal conditions most of the acids produced are acetic (70%), propionic (18%), and butyric (12%). These acids are absorbed through the fermentation vat wall into the portal circulation and transported to the liver where they become involved in metabolic processes. An appreciable amount of the energy requirements of the animal appears to be supplied by the short chained fatty acids.

The milk fat of ruminants is characterized by the presence of appreciable amounts of short chained fatty acids as compared to the fat of nonruminants. The dairy cow depends on the acetic acid produced in the rumen for an appreciable amount of the butterfat synthesized in the udder. The ingestion of high-grain (high-starch), low-roughage rations results in a marked lowering of the percentage of fat in milk. This fact is associated with a decreased production of acetates in the rumen. The supplementation of such rations with acetic acid or increasing the level of hay feeding causes the percentage of butterfat to return to normal. It is apparent that the present day dairy cow has become dependent on the vinegar (acetic acid) produced

by rumen microbes for the production of butterfat.

Ketosis is a disease that is more common among ruminants than nonruminants. There is a possibility that this disease may be due to insufficient production of propionic acid by rumen bacteria, since the feeding of propionates to affected cows results in recovery.

Microbes Make Good Proteins

Unlike animals with simple stomachs, such as poultry and swine who have a definite requirement for the essential amino acids included in their rations, cattle in common with other ruminants do very well when fed low quality protein rations. In 1939, critical experiments with rations that contained most of the nitrogen as urea or ammonium carbonate showed that cattle made satisfactory gains in body weight. Since that time, numerous experiments have shown that rumen microbes have the ability to convert the inorganic nitrogen compounds into microbial protein that contains all the essential amino acids. These findings are of great economic importance to the dairy industry since a part of the crude protein in roughages is nonprotein nitrogen. The dairy cow no longer needs to compete with monogastric animals for protein concentrates because urea (nonprotein nitrogen) is being produced in ever increasing quantities. Urea should be fed, however, with starchy concentrates such as corn and oats because it is converted rapidly to ammonia by the bacteria. The fatty acids produced from starch tie up the ammonia temporarily to enable the microbes to convert the ammonia into protein before it is absorbed. This accounts for the fact that urea is not toxic when fed in reasonable amounts as a part of the grain mixture. Usually it is advisable to limit urea supplementation to not more than 3% of the grain mixture. The most efficient use of nonprotein nitrogen is obtained only when urea is added to rations containing low levels of protein.

Rumen bacteria are also able to convert inorganic sulfur to the sulfur-containing amino acids (methionine and cystine).

Vitamin Synthesis in the Rumen

The first good evidence of vitamin synthesis in the rumen was given to the world by Pennstate Homestead Jessie, one of the most famous cows in history. A photograph of this historic cow is shown in Figure 3.

The cow carries her vitamin factory with her at all times and does not need to visit the corner drug store to get her supply of thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, folic acid, biotin, vitamin B_{12}, and vitamin K. All of these vitamins are made in amounts sufficient to meet the needs of the cow for maintenance and milk production. The liberal supply of these vitamins in the rumen of the cow

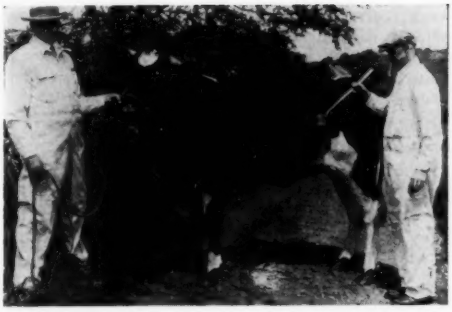

FIG. 3. The rumen contents from Pennstate Homestead Jessie showed for the first time that the microbes can synthesize the vitamin B complex. (Pa. Agr. Expt. Sta.).

insures the production of milk rich in these vitamins. Regardless of the type of ration fed, if milk is produced, it is rich in these vitamins. This is one of the important reasons why cow's milk is held in such high esteem by nutritionists all over the world. The only supplementary vitamins that may be needed in the ration of the cow are vitamins A, D, and E.

Keeping the Fermentation Vat Working

The cow is equipped with salivary glands, which secrete about 120 lb. of saliva daily. Some of the salivary glands produce saliva continuously, and others only respond to stimulation. About 5 lb. of saliva are produced per pound of hay consumed. The saliva, which contains 99% water, contributes to the maintenance of a high level of water in the rumen ingesta (75 to 85%) to aid the microbes in fermenting the feed. Then, too, the large amount of water in the saliva contributes to the water cycle. Some of the water that enters the rumen and is absorbed through the rumen and intestinal walls is returned to the rumen by way of the saliva. This aids in maintaining a high moisture content of the rumen ingesta even when cows have access to water only twice a day.

Ruminant saliva is characterized by its high alkalinity (pH 8.3); consequently, one of its functions is to aid in neutralizing the large amount of short chained fatty acids produced during fermentation. The reaction of the rumen contents is variable. Before feeding, when fermentation is at a low ebb, it is alkaline (pH 7.3), but as the tempo of fermentation increases after feeding, the ingesta becomes acid (usually to about pH 6.5). Under certain conditions, however, the rumen may be very acid (pH 5.0). In order to keep the rumen optimum for bacterial action some of the fatty acids are absorbed through the rumen wall.

The saliva aids in rumen fermentation by carrying compounds, such as cobalt salts, from the body to the rumen. It is believed that the

small amounts of urea present in cow's saliva help to keep the bacteria alive for short periods when the host is without feed. Long periods of fast, however, result in the loss of many types of microbes.

A compound is present in saliva that deodorizes the disagreeable odors in onions and garlic. This characteristic property of saliva explains why the writers of poetry and prose down the ages have raved about the sweet breath of the kine.

Cattle are noted for speed in eating roughages. Later on during the rest period, the coarse roughage consumed by the cow is regurgitated into the mouth for a second chewing. This act is called rumination. Early man, however, failed to recognize the fundamental basis of the dairy business, namely, the role of the rumen in the economical production of milk. Formerly man was so fascinated by cud-chewing (rumination) and regarded it so highly that all cud-chewing animals were classed as ruminants.

Cud-chewing has long been associated with solid comfort and contemplation. A common superstition during the early part of the present century was that the cud was actually a part of the cow and if she was so unfortunate as to "lose" it, she must have some special help to replace it. Many weird remedies have been proposed—a hunk of salt pork or an old dish rag were forced down the throat of a sick cow in an effort to supply this particular need.

It is obvious at the present time, however, that rumination is only a contributing factor to the efficient processing of the ingested feeds by the microbes living in the fermentation vat of the cow. Cud-chewing insalivates and macerates the coarse forage by creating more cracks and crevices for the bacteria to enter and do a better job of digesting.

The feeding of excessive amounts of either starch or sugar depresses microbial digestion of crude fiber. Usually not more than 2 to 4 lb. of molasses daily are recommended for dairy cows because larger amounts adversely affect digestibility. On the other hand, the addition of small amounts of molasses to poor roughage rations (corncobs) seems to aid the rumen microbes in fiber digestion.

In addition to the need for fermentable carbohydrates and proteins, minerals also are required to keep the microbes busy. The most dramatic mineral element in cattle nutrition is cobalt. For years cattle and sheep suffered from cobalt deficiency in many areas of the world. The disease has been known in various places by colloquial names such as "salt sick" in Florida, "lakeshore disease" in Michigan, and "burton-ail" in New Hampshire. About 22 years ago, Australian and New Zealand scientists found that trace amounts of cobalt fed to cattle and sheep brought about a dramatic recovery from this malady. Further investigations during recent years have shown that cobalt deficiency is actually a vitamin B_{12} deficiency. This vitamin, known as the "red mineral" vitamin, is produced in the rumen by bacteria. Cobalt makes up 4% of vitamin B_{12}. Colostrum contains a considerable amount of this vitamin and cow's milk is also a good source of the "red mineral" vitamin.

Gas Production

Although rumen microbes make possible the use of cheap nutrients from roughages, nevertheless there is a price which must be paid for this service, namely, the loss of energy in the form of gas. Large quantities of methane and carbon dioxide are produced, approximately 400 liters of each per day. The energy lost in these gases amounts to about 10% of the gross energy of the feed. This explains why monogastric animals, such as the pig, use energy from concentrates more efficiently than cattle.

Normally the cow has an efficient eructation mechanism and is able to "belch" several times as much gas as is ordinarily produced. This unique ability makes her the world's best "burper." Some of the gases, however, are absorbed into the blood and eliminated through the lungs. Under certain conditions the "burping" mechanism fails to work and bloat results. The physiology of eructation is not understood, but, according to a recent theory, the principal stimulus for this reflex is gas pressure in the rear dorsal blind sac of the rumen. A wave of rumen contraction starts in this blind sac and moves forward carrying the free gas to a position opposite the lower end of the esophagus; at the same time, relaxation of the reticulum (second stomach) clears the area at the lower end of the esophagus. Simultaneously, with these two events the lower end of the esophagus opens up like a funnel to allow the gas to pass out.

There are two kinds of bloat, *(a)* when there is a failure in the eructation mechanism which prevents the elimination of free gas, and *(b)* when the gas is held in the form of a stable emulsion or froth that prevents gas elimination.

The cause or causes of bloat are not known. The only workable method of preventing bloat in cattle is by pasture management. Since bloat is usually associated with a high percentage of legumes, especially alfalfa and ladino clover, the best prevention is the use of pasture which contains at least 50% grass. The danger of bloat is lessened when legumes are pastured at a more mature stage.

The Calf Becomes a Functional Ruminant

One of the problems in ruminant nutrition is to learn how to feed the young calf so the working fermentation vat is developed at an early age. The transition of the calf to a functional ruminant is probably a gradual one. Some evidence, however, indicates that the rumen reaches a functional status at 4 to 6 weeks

of age, as indicated by odor of the rumen contents and by the decline in blood glucose. The volatile fatty acid content of the rumen ingesta of calves is another indication of rumen microbial development. There appears to be a gradual increase in the quantity of these acids to about 9 weeks of age.

Young calves do not digest vegetable milk replacements efficiently until about 6 weeks of age. There is a possibility that the efficient digestion of starch and vegetable protein by the calf can take place only after the rumen microbes are present in sufficient quantity and quality to produce enzymes that are capable of handling these compounds. This means that the young calf is dependent on milk prior to the transition to a functional ruminant.

The calf probably obtains the desired kinds of rumen microbes from its mother and by association with older animals. The surgical removal of the rumen of the calf has resulted in either a marked tendency to bloat or a lack of appetite. Subsequently, the daily administration of rumen juice appeared to stimulate the appetite, accelerate growth, and improve general appearance. This emphasizes the role of the rumen in the formation of products essential for the maintenance of the health of the calf.

The Rumen and the Future

The future of the dairy business hinges, in no small degree, on using the architecture of the cow to the fullest extent to provide her the opportunity to convert the cheap nutrients in roughages into milk. This means fitting the roughage crops to the fermentation vat and fitting the microbes to the roughages. The fitting of the crop to the rumen means greater use of high-yielding immature roughages that can be converted into milk with a minimum of grain supplements. The only reason at the present time for feeding large amounts of grain to dairy cows is the low quality of the roughages. Grain is needed to balance poor roughage rations. Increased knowledge concerning the rumen, including the mechanical, chemical, and bacteriological aspects, will result in a better job of feeding for more economical milk production.

The role of the rumen in roughage consumption, although most important in greater roughage utilization, has received scant attention. Preliminary studies suggest that the rate of digestion in the rumen governs the dry matter intake. This is a fertile field for future studies. The effect of increasing salivary flow on the digestion and synthesis in the rumen by the microbes also awaits the probers of the future. Some of the pertinent questions that could profitably be investigated are *(a)* the possibility of encouraging the growth of methane-using microorganisms to eliminate or reduce the loss of energy from this source, *(b)* the role of different minerals in rumen fermentation, and *(c)* the status of the rumen bacteria in metabolic disorders of cattle.

The slogan of the dairyman should be "more milk per cow and more milk per acre."

Dairy Cattle Genetics

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In 1906 enthusiasm about the practical results to be had from applying the recently rediscovered Mendel's Law was running high among a few of those who had heard of it, although many still thought that Mendelism applied to only a few superficial characters.

J. L. Lush

Late in December of 1903 the enthusiasts had met in St. Louis to pool their ideas and form the "American Breeders Association." The American Association of Agricultural Colleges and Experiment Stations had encouraged them to do this, and the American Association for the Advancement of Science had helped organize the meeting. Both plant and animal breeders, applied as well as theoretical, participated. Letters of encouragement came from men with diverse interests and ways of looking at things, such as Governor Hoard, E. D. Davenport, Luther Burbank, and Agricultural Secretary James Wilson. W. M. Hays of Minnesota was the secretary and C. F. Curtiss of Iowa was the first chairman. Laboratories for the study of heredity and practical animal breeding had already been formed at the University of Chicago and at the Agricultural Experiment Stations of Maine, Minnesota, and Missouri.

The Proceedings of the first and second meetings of the A.B.A. were printed in 1905. One who wants to know more about what was known, thought, or hoped about animal and plant breeding in that decade can hardly start better than by scanning the Proceedings of the first eight annual meetings. Among the officers and participants in the first two meetings are many names well known to workers in dairy science, such as: A. J. Glover, F. B. Mumford, Oscar Erf, W. E. Castle, and W. J. Spillman. In 1910 the A.B.A. began to publish a quarterly, the *American Breeders Magazine* which, after four volumes, was renamed the *Journal of Heredity*, under which title it still appears. By 1916 genetics also had become intricate enough to need a more technical journal. *Genetics* was launched that year. Most papers on dairy cattle genetics in recent decades in the United States have appeared in the *Journal of Dairy Science*, *Journal of Animal Science*, or *Journal of Heredity*, according to whether the contents were thought to bear mainly on dairy cattle, or on other farm animals also, or whether they would be of interest to geneticists in general or to the general public.

Establishment of Mendelism

In the two decades from 1900 to 1920 the main interest of geneticists was in verifying Mendelism and identifying its physical basis as the chromosome mechanism. That was rather generally conceded by 1919 when East and Jones could write: "Mendelian heredity has proved to be the heredity of sexual reproduction; the heredity of sexual reproduction is Mendelian." But the number of genes turned out to be so large and their ways of interacting with each other so unpredictable and infinitely numerous that most of the early hopes of quick applications of simple Mendelism to practical plant and animal breeding grew dim.

Biometrical methods of studying heredity were developed by Galton and his associates long before Mendelism was rediscovered. At first some workers thought that the Galtonian and Mendelian methods and ideas conflicted, but by 1920 this had been rather generally reconciled or explained by the work of such men as Hardy, Pearl, Jennings, Wentworth, Robbins, and many in the Scandinavian lands. Through the 1920's and 1930's intensive work on special topics laid the broad foundation for what is now generally called "population genetics." Three of the main architects of this work—Fisher, Wright, and Haldane—published in 1930, 1931, and 1932 works so complete that one rarely needs now to look at earlier work on population genetics, unless he is interested in the history of the ideas. Since the early 1930's these ideas have been extended in many ways, especially to exploring the mating structure of breeds of farm animals and even of local races of many wild species.

Geneticists in the last two decades have worked intensively on the causes and nature of mutations and on the physiology and chemistry of how the genes actually produce their effects. Basic knowledge has been increased considerably but practically none of this has been done on dairy cattle, since cattle are unsuitable organisms for this. The inevitably numerous mistakes while first clarifying basic principles are far more cheaply made on simpler laboratory organisms.

The first Mendelizing character reported for cattle was the contrast between horns and polledness, recorded in 1902 by Bateson and Saunders and in 1905 by Spillman. The list of definite genes is now long and continues to grow but, as is true with most other livestock

and with man, includes a high proportion of lethals, abnormalities, and details of color or structure that have little or no obvious relation to utility or fitness. Characters economically important, such as growth rate, milk and fat production, and general health are affected by so many genes that identifying them individually in the classical Mendelian way is difficult or, more often, impossible. Definite genes currently of major interest in dairy cattle are those controlling the blood antigens, of which an unexpectedly large number have been found. These include some of the longest series of multiple alleles yet known to genetics. Practical applications in settling cases of disputed parentage are already numerous.

The better informed breeders of dairy cattle in 1906 were already well informed about Darwin's views and Galton's attempts to quantify the observed facts of heredity. The Mendelian discoveries did little at first to change their operations but did much to take the mystery out of many hitherto puzzling things, such as atavism, reversion, hybrid vigor, inbreeding, regression toward the breed average, and the frequent unlikeness of full sisters. Also, it put a more solid floor under the reasonable use of progeny tests and of pedigrees. Between 1906 and 1930 many stations conducted grading experiments to measure and demonstrate the results of grading to purebreds. Knowledge of Mendelism helped in interpreting the results, although the projects probably would have been undertaken anyhow, since they fitted well the general background of breeder knowledge.

Beginning of Crossbreeding and Inbreeding Studies

Crossbreeding and inbreeding experiments with dairy cattle were begun before 1920 at several places, such as Tranekjaer in Denmark, the Maine and Wisconsin stations, the University of Illinois with the Bowlker herd, and at Beltsville by the USDA. The basic genetic theory of inbreeding was not well clarified, especially for irregular systems, which are all that are possible with the larger farm animals, until Wright's classic papers on mating systems appeared in 1921. Those, in turn, Wright probably would never have written if he had not had the task of interpreting the results of the extensive experiments on inbreeding guinea pigs begun by the USDA in 1906. This is the classic cycle or spiral of theories revised or clarified to fit the results of exploratory experiments; then new experiments with better design were conducted and the theories were again revised to fit the new data; then new experiments were designed to focus more sharply on the questions newly seen to be most pertinent, and so on. By 1930 the California, Texas, New Jersey, and Iowa stations had started inbreeding experiments with accompanying emphasis on selection that could hardly have been formulated before 1920.

Emphasis on selection called for more knowledge about repeatability and heritability of different kinds of records and of the proper allowances to make for any environmental circumstances that were worse or better than those chosen as standard. Data for studying these came mostly from D.H.I.A. records or from the official testing or H.I.R. files of the breed associations, although a few were from designed experiments. The spread of artificial breeding has widened the possibilities of getting knowledge by making abundant some formerly rare types of data. For example, the daughters of a bull used artificially are scattered through dozens of herds, and many individual herds will each contain contemporary cows sired by three or more bulls.

Widening of Study

As heritability of individual traits began to be clarified and selection indexes were developed, the need for knowing genetic correlations between different traits became more acute. The idea was not wholly new, although the distinction between genetic and phenotypic correlations was nearly so. Already in 1905 at the second A.B.A. meeting A. J. Glover had a paper on "Form and Performance." Thomas Bates, more than a century ago, had some data and emphatic opinions on the subject. In the last decade the methods of Fairfield Smith and Hazel have been used often to estimate genetic correlations. Answers are becoming clearer although their sampling errors are still regrettably large.

One can now compute, as Robertson and Rendel have done for milk yield, the rates (although not the limits) of genetic improvement that are reasonably possible for whole populations of dairy cattle and how these would change with certain changes in procedure. Some of the parameters are known only within wide limits, and much is uncertain about how closely the human beings who will do the work will come to achieving that which is biologically possible, but at least a good beginning has been made.

Experiments on identical twins in dairy cattle, largely as yet in Sweden, New Zealand, and Scotland, have indicated that heritability is much higher than the resemblances between daughter and dam or between sisters indicate. Whether the difference can be explained by dominance and epistasis, or by unexpectedly strong maternal influence, or by each genotype being well or ill adapted to an array of environments peculiar to it, or by some yet unformulated circumstances is for the future to unravel.

Developments in the Physiology of Reproduction of Dairy Cattle and in Artificial Insemination

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A study of the physiology of reproduction in animals and of other fields of natural science began with the dawn of man. His existence depended upon his skill in killing animals for food, and because of this critical necessity he developed hunting lore, which included knowledge of the mating and young-bearing habits of wild life. Observations of animals recorded on walls of caves, and undoubtedly writings on natural science that have been lost, antedate Aristotle (384-322 B.C.) by as much as Aristotle antedates our time. In spite of the antiquity of natural science, man has learned more about reproduction of the bovine during the past half-century than was learned in all previous ages. This statement applies as well specifically to artificial insemination as it does generally to reproduction. Actually, little information was available concerning reproduction of cattle at the time of the founding of the American Dairy Science Association in 1906. Scientists at that time, however, were beneficiaries of a rich heritage of fundamental information concerning reproductive processes.

E. L. Willett

This paper, firstly, gives the reader a glimpse of this heritage, then outlines progress during the last half-century concerning knowledge of reproduction with special reference to the bovine, and lastly makes a few remarks and predictions.

The Heritage

Disciplines in physiology. During the nineteenth century all of the sciences experienced remarkable advances far surpassing those in any previous comparable period. Although countless people back through the ages contributed to this progress in one way or another, it will suffice to start with the first observation of spermatozoa by Leeuwenhoek in 1679. He made microscopes and was the first to observe and describe red and white blood cells, reproduction of fleas, compound eyes of insects, bacteria, yeast, and "animalcules," or spermatozoa. Neither Leeuwenhoek nor his contemporaries, however, understood the importance of the discovery of these animalcules. Later workers gave to them the name of spermatozoa (sperm animals) because they were considered to be parasites. When spermatozoa came to be associated with reproduction, various men, including Leeuwenhoek, imagined they saw the adult body in miniature form encased inside the spermatozoan membrane. Thus arose the preformation theory. Furthermore, Leeuwenhoek thought that all that was necessary for the growth of young in the spermatozoon was the environment of the uterus. Others thought that the "fruitful soil" of the female egg was all that was needed. As a result of early studies of the development of the chick, other men conceived the idea that the ovum contained the adult in miniature as a bud contains a flower. Thus a great controversy developed between the "spermatists" and the "ovists." Arguments were presented by eminent biologists to support their respective beliefs. These philosophers believed that all answers could be attained by speculation, and they scorned experiment. This domination of speculation over experimentation was prevalent in all branches of learning throughout the eighteenth century and well into the nineteenth.

The experimental method did not attain its rightful place in science until the nineteenth century. In the first half of that century chemistry and physics made splendid progress. Berzelius, who has been termed the creator of the science of chemistry, defined the method which was used so productively in those fields by himself and his contemporaries: "I have everywhere sought to avoid hypothesis, and where I have at any time ventured to make insignificant guesses, they are all of such a nature that they will soon be decided by experiment. I prefer to say: 'This is entirely unknown to us,' than to try by means of a number of probabilities to gloze over a gap in our knowledge." Biologists saw the fruitful results of the experimental method and adopted it.

Another factor in the rise of biology during the twentieth century was the improvement of the microscope and the development of microscopic techniques. In the earlier instruments, such as Leeuwenhoek's, fairly high magnifications were attainable, but a colorless object under the microscope would shimmer with all the colors of the spectrum. This fact caused many misinterpretations of objects observed. Achromatic lenses corrected this difficulty, and other improvements in the microscope followed. Techniques for fixing, paraffin embedding, and staining of tissues were developed, and the modern microtome was introduced in the latter half of the nineteenth century.

Improvement in the microscope enabled biologists to search more deeply into the mysteries of living matter than they had previously. One of the most important outcomes of this widening of

the horizon was the development of the concept that the cell was the unit of life in both plants and animals. The science of cytology progressed steadily until it reached its zenith in the last decade of the nineteenth century, during which time a burst of activity virtually completed our general knowledge of the fertilization process. The development of this process will be discussed in more detail later.

In the middle of the nineteenth century there appeared a publication which probably had a greater impact upon biology, as well as upon all phases of men's thinking, than any other work during the past century. This was Darwin's *Origin of Species by Means of Natural Selection*, published in 1859. This book explained that the origin of species was brought about by dissimilarity between the offspring and the parents—variation—and the struggle for existence with resulting natural selection and survival of the fittest. Because of the resulting controversy and the search by Darwin's supporters for additional evidence for his principles, research in biology was greatly stimulated. In Germany proofs of the descent theory were sought through comparative anatomy and embryology, and in England (notably Galton) by means of experimental and statistical methods. Between 1870 and 1890 Germany came into prominence in biological research and was followed by England, America, Italy, and France. Toward the close of the century anatomy and morphology dominated all fields of biology, and physiology, although still active, was relegated to a minor rank. This situation, however, certainly was not without benefit, for without knowledge of anatomy and the realization in the late nineteenth century of the dependence of form upon function, physiology would have been seriously handicapped.

Germ cells and fertilization. "Undoubtedly the greatest service to biology that has been performed by modern cell-research is its having given us our present knowledge of the course and significance of fertilization—a discovery worthy to be placed by the side of the explanation of the circulation of the blood in the seventeenth century." — Nordenskiöld.

As mentioned previously, Leeuwenhoek and others of his time did not understand the significance of spermatozoa. It was not until over a hundred years later that an approach to the answer was made by Spallanzani, an Italian. He proved that semen was necessary for fertilization of the egg by placing panties of waxed taffeta upon male frogs. The males with the panties did not fertilize eggs; those without the panties did. Later it was found that spermatozoa were the essential part of semen and that they were produced in the testis.

Elucidation of the part played by the female germ cell in reproduction began with a study of the ovaries of rabbits, reported by de Graaf in 1678. He described the follicle (to which his name is given) but erroneously thought that it was analogous to the avian egg. He also found developing embryos in the oviducts and uteri, but he could not explain the difference in the large size of the follicles and the small size of the embryos.

The role of the germ cells in reproduction was clarified in the latter half of the nineteenth century by embryologists and cytologists with their microscopes. De Graaf's riddle with rabbit eggs was solved by von Baer in work with dogs. He recognized eggs in various stages of development in the oviduct and was able to trace them back to the follicle. Other workers later observed spermatozoa in ova and, with other evidence from various species, obtained irrefutable proof that the union of spermatozoa and eggs was essential for reproduction.

Thenceforth cytology, which prior to this time had been concerned with histology and embryology, solved step by step some of the mysteries of fertilization which take place inside the egg. This was accomplished by working with sea urchins, earthworms, insects, round worm of the horse, and other lower forms of life. That these principles applied to the mammal was demonstrated by Sabotta with mice in the 1890's. His classical descriptions included the second maturation division which follows penetration by the spermatozoon, extrusion of the second polar body, alteration of the head of the sperm cell to form the male pronucleus, growth of the nuclei, and the formation of the chromosomes in the first reduction division. To obtain all steps in this process, Sabotta prepared and fixed 1,197 eggs in all stages.

It was not until the first decade of the twentieth century that heredity and cytology were joined. Mendel's classical experiments with peas were rediscovered. Sex determination was connected with the chromosomes. First cytological evidence that chromosomes give a mechanical explanation of Mendel's laws was presented. Our modern concept that structural units on chromosomes, now called genes, are the carriers of genetic characteristics from one generation to the next began to evolve.

One of the interesting outgrowths of this development of knowledge of fertilization and its part in the "marriage" of cytology and heredity was the concept that any living organism is one of many streams of life. These streams have as their source the beginning of life. The reason is that a cell always grows from another cell, and germ cells descend from germ cells. They live on from generation to generation and carry the characteristics of the race from the distant past to the unknown future. Therefore, the animal body is a side-development from germ cells and, as far as the species is concerned, is of little importance. This is our modern concept of heredity and was the basis of the words expressed by Samuel Butler (quoted by Wilson): "It has, I believe, been often remarked that a hen is only an egg's way of making another egg."

Endocrinology. This is one of the newest branches of physiology. During the first half of the nineteenth century, much progress was being made in the other fields of physiology. There was, however, no suggestion of the importance of endocrine secretions until almost the end of that half-century. Berthold in 1849 demonstrated in the fowl that the testes were capable of exerting an influence upon body functions and characteristics through the blood stream and not by nervous connections. Another fundamental concept, demonstrated by Claude Bernard, was that animals, as well as plants, are able to synthesize substances. He coined the term "internal secretions," associated this function with various organs and glands of the body, and originated the principle that the normal composition and function of the body is maintained by these secretions.

Endocrinology as a science is said actually to have begun in 1888. In that year Brown-Séquard, 72 years of age, made a historic report to the Society of Biology in Paris. He had made aqueous extracts of dogs' testes and had injected them into his own body. He told the Society, in all intimate detail, of his remarkable rejuvenation. In light of present knowledge we know that his results must have been more psychological than real. Nevertheless, the important outcome of his work was that he introduced the technique of injecting extracts from glands and that he called the attention of physiologists to the problem of endocrines. As a result of his dramatization, this field received a tremendous impetus, and rapid strides were made thenceforth.

Marshall, in his classical book entitled *The Physiology of Reproduction*, in 1910 summarized the state of knowledge concerning the testes and ovaries as organs of internal secretion as follows: "The principal evidence supporting the theory that the ovary and testicle are organs of internal secretion is derived from the experimental study of the effects produced, first, by removing the organs, and second, by transplanting them to abnormal positions in the body. Experiments of such a kind clearly demonstrate the influence of the ovary and the testicle upon the growth and development of the other generative organs, and upon the secondary sexual characters. They indicate, moreover, that the nature of this influence is chemical rather than nervous. Certain further evidence, which is less satisfactory in character, has been obtained from experiments on the injection of ovarian and testicular extracts."

These statements certainly indicated that the secretions of the ovary were associated with certain sexual phenomena in the female. This function was attributed in large part to the corpus luteum, however. Experiments in the first decade of the twentieth century proved that corpora lutea are associated in some cause and effect manner with pregnancy and that the corpus luteum is essential in dogs and rats during early, but not during advanced, pregnancy.

The factors causing estrus were much less clear. Some believed that the corpus luteum was involved. German workers showed by transecting the spinal cord that heat in animals is not brought about by a "cerebral or spinal reflex." Heape suggested in 1905 that a "generative ferment" was present in the blood. The elaboration of this ferment was stimulated by favorable climate and nutrition. It caused an increased activity of the generative glands which, in turn, acted upon the rest of the generative system and possibly other organs by means of another ferment secreted into the blood. He named this last secretion "gonadin." Marshall and Jolly in 1905 showed with rats that ovaries in a proestrous or estrous condition, when transplanted into an ovariectomized animal, brought about estrus. They pointed out that, as far as they were aware, no animal experiences proestrus or estrus in the presence of a corpus luteum. On the basis of available evidence they hypothesized: *(a)* Heat is produced by an internal secretion from the ovary elaborated by the follicular epithelial cells or by the interstitial cells of the stroma. *(b)* This ovarian secretion has a marked effect upon the other reproductive organs and also on the nervous system, as evidenced by the behavior of an animal in estrus.

In regard to the testis, it was shown in 1849, as mentioned above, that this organ was associated with secondary sexual characteristics, and this work had been confirmed prior to 1906 by other workers. Nevertheless, the site of production of the hormone was not determined. It was suggested, however, that the interstitial cells produce the necessary "pro-secretin."

The role of the placenta as a source of hormones was still far more obscure than that of the testis. Scattered evidence, mostly with humans, suggested that the placenta may serve as a secreting gland. Experiments reported in 1905, 1906, and 1907 indicated that the placenta secretes a hormone which stimulates development of the mammary gland and lactation. It was suggested by Marshall in 1910 that the factors concerned with maintenance of pregnancy and lactation initially were derived from the ovary but that this source was replaced by the products of conception (fetus and/or placenta) as pregnancy progressed. Lane-Clapon and Starling in 1906 prepared extracts from various reproductive organs, injected them into female rabbits, and compared mammary development. Their work suggested that the fetus, rather than the placenta, was the source of the hormone. They stated: "A striking feature in all our experiments with a positive result is the smallness of the growth produced as compared with the quantity of material used for injection." Their difficulty may be explained, at least in part, by the fact that aqueous sodium chloride was used in preparing their extracts.

It is now known that the estrogenic and androgenic hormones are steroids, which are only slightly soluble in water. Furthermore, in most glands the active principles are present in low concentrations and must be purified and concentrated to get potent extracts. These facts explain why Brown-Séquard's rejuvenation was largely psychological and why aqueous extracts of reproductive organs gave uncertain results, as mentioned by Marshall.

In 1906 little was known concerning the relation of other endocrine glands to reproduction. Hypertrophy of the pituitary had been noted in castrates of various species. It was also observed that, in cases of gigantism and acromegaly, the pituitary was enlarged and the uterus was infantile and ovaries rudimentary, or the penis was underdeveloped. There was some evidence, also, that there was a reciprocal relationship between the thymus and the testis.

Reproduction of the mammalian female. In 1900 Heape originated the terms "pro-oestrum," "oestrum," "metoestrum," and "dioestrum" to indicate the different stages of the mammalian estrual cycle. He gave the word "anoestrum" to the period when the reproductive organs were quiescent. Marshall, in histological studies of the reproductive organs of the sheep in 1904, found that ewes ovulated independently of coition. In the following year Heape, in a similar study with rabbits, found that they ovulated only as a result of mating and then approximately ten hours later. In another paper he concluded that cows ovulated spontaneously because they conceived from artificial insemination. Prior to 1906 there apparently had been no detailed study of the histology of the reproductive tract of the cow. A number of general observations had been made by various workers. These included such items as weights of ovaries, gross examination of corpora lutea, and histological sectioning of the uterus after estrus. Nor had careful observations of the temporal factors in reproduction, such as time of ovulation and length of estrus and of the cycle, been carried out. It was believed that ovulation of all farm animals coincided with estrus.

The stimulus for ovulation was obscure. Heape believed that ovulation was brought about, at least in the rabbit, by the stimulation of erectile tissue in the ovary as a result of a nervous reflex induced by the act of copulation. It was believed that, following ovulation, the egg was guided to the Fallopian tube because the fimbria enclosed the ovary and because cilia produced a current which aided in moving the egg toward the oviduct. It was known, also, that eggs were sometimes produced in an ovary on one side but migrated through the peritoneal cavity to the oviduct on the other side. It is of interest to note that Heape in 1890 demonstrated that ova would develop normally when transferred from one rabbit doe to another.

As early as 1910 Marshall realized the part that embryonic mortality can play in apparent infertility. When referring to differences in apparent fertility of ewes observed by Heape, Marshall said: "It is possible that what in this case appears to be barrenness is in reality very early abortion, the inbred embryos tending to die at an early stage and to be absorbed *in utero,* thus escaping observation."

According to Assheton, three or four days are required for travel of the egg from the ovary to the uterus in the ewe. After the blastocyst is formed, the zona pellucida is lost and the trophoblast develops. This latter structure aids in nourishing the embryo by ingesting nutrients, including erythrocytes, from the uterine milk, which is formed by glands in the endometrium. Considerable study had been made by various workers in the chemical composition of this uterine milk. Changes in the uterus during pregnancy and development of the placenta had been studied in detail in some of the ungulates, including the sheep, by Assheton and others. No histological changes were detected by Assheton in the endometrium prior to arrival of the embryo in the uterus. However, according to his observations, after the egg's arrival blood-vessels and lymphatics dilated, and glands widened and became tortuous. In the sheep attachment of the embryo to the endometrium began on the seventeenth day following coitus, and implantation was completed on the thirtieth day. A study of a twelfth-week placenta of a cow by Assheton indicated that the placenta was similar in most respects to that of the sheep. The function of the cotyledons in the placenta was well understood.

Concerning the cause of parturition, Marshall quotes Foster (1891) as follows: "We may be said to be in the dark as to why the uterus, after remaining for months subject only to futile contractions, is suddenly thrown into powerful and efficient action, and within it may be a few hours (sic), or even less, gets rid of the burden which it has borne with such tolerance for so long a time. None of the various hypotheses which have been put forward can be considered as satisfactory. We can only say that labor is the culminating point of a series of events, and must come sooner or later, though its immediate advent may sometimes be decided by accident." In general this quotation still applies today. Several physiologists had demonstrated that normal parturition took place when all nervous connections from the uterus to the cerebrospinal system had been severed. Of the eleven theories discussed by Marshall, not one of them mentioned the possibility that secretions from the ductless glands might be a factor in parturition. Some interesting observations had been made concerning uterine contractions. It was noted that their intensity increases toward the end of pregnancy. Also, an increase in intensity was likely to occur postpartum when "a child was put to the breast, a fact which seems to

indicate a nervous connection between the uterus and the mammary glands." Marshall also mentioned that "emotions often become a hindrance to the progress of parturition." When these words were written it was not known that oxytocin from the posterior pituitary gland causes contractions of smooth muscle and that this action can be inhibited by adrenaline.

Reproduction of the mammalian male. Prior to 1906 the cytology of spermatogenesis had been described in detail. Wilson in the second edition of his book, *The Cell in Development and Inheritance,* published in 1902, reviewed the literature. Most of this work was done with lower animals, including amphibians, insects, and earthworms, but studies with various species of mammals, including rat, guinea pig, and man, indicated that the general features were similar in all these species. Considerable study also had been made of the structure of spermatozoa. The acrosome was described, and the axial filament had been found to consist of a number of parallel fibrillae. It was known that the nucleus comprises the main portion of the head, which is somewhat flattened.

As a measure of the vitality of spermatozoa, Marshall and Jolly ligated the vas deferens of a dog and of rabbits. Motile spermatozoa were observed in the autopsied males up to ten days after ligating. It was known that spermatozoa progressed slowly down the male tract and that they were immotile during this time. Ivanoff, a Russian, however, had shown that spermatozoa from the epididymis of bulls, horses, and other species were capable of fertilizing ova in inseminated females and that the secretions from the male accessory glands were, therefore, not required for fertility. Disselhorst, a German, suggested that the ampulla serves as a storage place for spermatozoa and that there is a relation between the size of the ampulla and the time required for copulation. When small or absent, copulation time is long, as with dogs and boars; when large, as in horses and sheep, copulation is relatively short. Marshall stated that unejaculated spermatozoa degenerate and liquefy. Ivanoff stated that his finding of spermatozoa of poor motility and morphology in semen after a period of abstinence by a sire confirmed this belief. It is of interest that various workers had found that spermatozoa of the bat and some insects remain quiescent for long intervals of time in the female without losing their ability to fertilize ova.

It had been observed that spermatozoa become active immediately after ejaculation. Lott, a German, estimated that spermatozoa swim at a rate of 3.6 mm. per minute in vitro, and Bischoff in 1842 found spermatozoa near the ovary in the rabbit nine or ten hours after mating. Ivanoff believed that semen was ejaculated directly into the uterus in farm animals. Marshall stated that the passage of spermatozoa through the uterus was facilitated by muscular contractions. According to several German workers, spermatozoa traverse the oviduct under their own power and in opposition to currents set up by the cilia of the epithelia. Heape observed the sucking action by the rabbit uterus which assisted the passage of spermatozoa into the organ. Marshall stated: "The contraction of the uterus is said to be a reflex action resulting from copulation. . . . Pregnancy has been known to follow imperfect coition in Man, so that there can be no doubt that under certain circumstances the spermatozoa are capable of passing inward by their own unaided efforts."

The function of the accessory glands of the male was in doubt. According to Marshall, one possibility was that the seminal vesicles serve as a storage place for spermatozoa, but most physiologists considered their main function as being secretory by providing a fluid medium for transportation and also possibly nutrition of spermatozoa. As mentioned above, Ivanoff proved that the accessory secretions were not required for fertility. Lode, in a German publication in 1895, showed that in young animals in which one of the testicles was removed, the corresponding seminal vesicle continued to grow and to become filled with its characteristic fluid. This was given as evidence that the glands were undoubtedly secretory. He also found that the glandular epithelium of the seminal vesicles atrophied in castrated bulls and other animals. There was some evidence that secretions from the prostate had a stimulating influence upon motility of spermatozoa.

Ivanoff apparently was a keen observer of animal behavior. He noted among farm animals that some females were "attractive" to males, and others not. The same was true in regard to attractiveness of males to females. He stated that this field merited extensive study in relation to the problem of libido.

According to Marshall, more was known about the chemistry of spermatozoa than about any other cell. He said: "The chemical analysis of the spermatozoon is . . . complete. It shows that the tail is very rich in phosphorised fats which are accompanied by cholesterin, fats, and a typical protein. The head consists almost entirely (96 per cent) of a substance—a nucleoprotein—one component of which is constant for the different species and classes—the nucleic acid. The other more or less basic component varies widely for the different classes of vertebrates and shows minor variations for the different species in any one class. Besides this nucleoprotein, another organic substance, containing iron in organic combination, is present in very small amounts." The comparison of chemical analyses of spermatozoa of different classes of vertebrates included the bull. For this species the basic component of nucleoprotein other than the nucleic acid was said to be neither protamine nor histone, as was the case with lower vertebrates. One-half of the nonnucleoprotein fraction of the head of the spermatozoon was reported to consist of inorganic

salts, mainly calcium phosphate and calcium carbonate, while the other half, the remaining 2%, consisted of an unrecognized organic substance containing 0.12% iron. Prior to 1906 a number of chemists and physiologists had tried to determine the chemical mechanisms involved in fertilization. No ferment or enzyme had been found in the spermatozoon that appeared to play a part in this process.

Artificial insemination. Actually, man did not originate the practice of artificial insemination. For this, credit must be given to a number of species of the lowly spider. Males of some species are not endowed by nature with copulatory organs. As a result, they deposit semen on a small mat spun by themselves, dip their feelers into the semen, and plunge the sperm-laden feelers into the abdomen of the female.

Only a few years after man's first authentic use of artificial insemination by Spallanzani in 1785, Hunter recommended that the technique be employed in a case where the husband had a physical deformity preventing normal coitus. Results were successful. A century later the practice was in common use in the United States with horses. This was done when sterility was caused by abnormal structure in the mare, vaginal secretions, or muscular contractions causing expulsion of semen, or when it was desired to breed several mares to a stallion at one time. Heape learned the technique by correspondence with men in the United States and described them in 1897 as follows. A stallion bred a mare. Semen was aspirated from the vagina by means of a special nozzle and syringe and injected into the uterus of one or more mares by the same apparatus. Another method of insemination was to fill gelatin capsules with semen and to force them into the uterus. It was considered highly important that semen be maintained at body temperature. Heape also remarked: "It is said that artificial insemination can be performed on cows as readily as it can on mares, but I have seen no published account of experiments on cows." Ivanoff in 1907 reported the adoption in Russia of American methods for insemination of mares. He apparently improved upon these methods by placing a rubber condom on the penis of stallions to collect semen.

Ivanoff also initiated experiments in 1902 to artificially inseminate cows. Semen was obtained by placing a sponge in the vagina and squeezing out the semen after service or by aspirating spermatozoa from genital organs removed from bulls at the abattoir. He obtained spermatozoa with better motility from the epididymis than from the vas deferens. He diluted semen in either Locke's solution, 0.85% sodium chloride, or 1% sodium bicarbonate in water. If it was desired to store semen for a period of time, epididymides were refrigerated, and the spermatozoa were removed later for insemination. When discussing the practical application of artificial insemination he stated that the distance that the spermatozoa could be transported for artificial insemination was the distance traveled in two hours, and survival of spermatozoa was longest when stored at a temperature of 2° C. The semen was deposited in the vagina of the cow. The list of equipment for artificial insemination included a candle with reflector to illuminate the vagina, speculum, tweezers for inserting and removing sponge, and suitable catheters. This work by Ivanoff represents the first concentrated effort made to study and develop methods and techniques for the improvement of artificial insemination in the bovine, and possibly in any of the farm animals.

A Half-Century of Progress

A cartoon once depicted a pygmy sitting on the shoulders of a giant, and underneath were the words: "A pygmy sitting on the shoulders of a giant can see farther than the giant." Thanks especially to the background of fundamental research by men during the half century preceding 1906, physiologists since 1906, whether they have been pygmies or giants, have been able to see and understand phenomena which were beyond the view of the giants of yesteryear and have been able to broaden ever further the horizons of our knowledge.

Disciplines in physiology. The rate of growth in research activity and resulting knowledge during the past century has been exponential in nature. As a consequence, knowledge in physiology has increased beyond the grasp of one man, and workers now specialize in various branches within this field. Because of the complexity and fundamental character of many modern problems in physiology, the physiologist has had to call upon various other disciplines for assistance. For this reason there are biochemists, radiobiologists, biophysicists, and biometricians, as well as men in numerous other fields, working on physiological problems. Much research, therefore, is now done by men in different specialties who pool their knowledge and methodology to solve problems.

With the rapid growth of knowledge during this last half-century several trends have had a marked influence upon the world picture of science, including physiology of reproduction. Prior to 1906, the emphasis was on fundamental research—the search for knowledge for the sake of knowledge and without any definite practical application. The world center of science was Europe, especially Germany and France. Various forces, including two devastating wars in Europe and accompanying social, political, and economic changes, caused a shift of the center of world science from Europe to this country. In Europe the emphasis had been upon fundamental research; in the United States there has been an increasing emphasis upon applied research—the search for knowledge that has a direct, practical application. In fact, in this country, of all money now spent for research,

only about 5% supports fundamental research. The applied researchers have been drawing upon the reservoir of knowledge acquired by fundamental research without replenishing the supply. Important factors in this emphasis upon applied research have been the great increase in research by commercial organizations and by the government for defense purposes.

Since 1906 the experimental method has been developed and refined until it has become a discipline in itself and a branch of mathematics. The techniques developed enable researchers to design, analyze, and interpret the results of their experiments in a manner that will enable them to obtain information with maximum efficiency. The relationships between variables can be studied and interpreted mathematically and conclusions can be drawn in terms of the laws of probability. Experimental designs are now available which enable the comparison of a number of variables simultaneously. These are especially useful in physiology where many phenomena are complex ones and involve many interacting variables. The hormones in reproduction are one example. The field of statistical methods and experimental design has been an especially active one during the past decade.

Scientists have been delving ever deeper and deeper into the minute and intricate workings of tissues and cells. In this pursuit microscopy has continued to play a major role. Electron microscopes produce magnifications up to 35,000 diameters and when used with microincineration make possible the localization of minerals. By means of "shadowing," a three-dimensional effect can be created. The phase-contrast microscope enables study of structural details in living or unstained cells and tissues in lieu of the usual fixed and stained material with possible artefacts. Ultraviolet and fluorescence microscopy are additional tools facilitating the study of structure and chemical composition of cells and tissues. The volume and dry matter content of cells and intra-cellular structures can now be determined by use of the recently developed interference microscope. Identification of cell and tissue constituents and their localization have been made possible by cytochemical and histochemical techniques such as radioautography, and quantitative measurements can be made of some compounds by means of microspectroscopy. Micromanipulators, with easily controlled movements delicate to the limits of resolution of ordinary laboratory microscopes, permit manipulation and dissection of tissues and cells.

The chemist now plays a major role in all phases of physiology. With his micro techniques he can measure minute amounts of compounds quantitatively. He has found that the labeling of compounds by means of radioactive isotopes is a useful tool in studying many physiological processes.

The development of techniques for growing and maintaining cells and tissues in artificial media in vitro has been another tool which the physiologist can employ for the study of many problems.

Endocrinology. After 1906 and during the first quarter of the twentieth century some progress was made in the field of endocrinology of reproduction. However, by far the greatest advances have been made during the second quarter of this century. For many of these advances we are indebted to the biological and organic chemists, who have extracted, purified, determined the chemical properties of, and in many cases synthesized, the hormones. With highly purified preparations the physiologist has been able to study and learn their biological properties.

Marshall's brilliant hypothesis that the estrus-producing hormone is elaborated in the follicle was conclusively confirmed by histological studies reported from 1917 to 1922. In 1923 Allen and Doisy injected fresh, and alcohol-soluble extracts from, pigs' follicular fluid into ovariectomized mice and rats. Typical estrous changes were observed in the reproductive tracts. Crystalline estrone was prepared by Doisy in 1929. Four years later Schwenk and Hildebrandt obtained estradiol by reducing the ketone group of estrone. Estradiol is probably the hormone naturally occurring in the ovary and is the most active of the natural estrogens. Other steroids have been found to have estrogenic activity, but it has also been found that chemical compounds other than steroids have similar biological properties. In 1933 Dodds and associates in England obtained a stilbene derivative with estrogenic activity and in 1938 reported the preparation of diethylstilbestrol. This highly active synthetic and inexpensive compound has found wide use by the medical profession and by livestock feeders in fattening rations. Synthetic estrogenic stilbene derivatives and steroids produced by organic chemists now number in the dozens and have highly variable activities. Estrogens have also been found in considerable quantities in urine of pregnant women and in urine of stallions. Oddly enough, the concentration in the urine of stallions is 400 times that in the urine of women. The physiological significance of this fact is unknown. Estrogens have been found in various plant substances. A flavone, genistein, is in subterranean clover in sufficient amounts to cause sterility in ewes in Australia.

Marshall and Jolly's work in 1906 demonstrating the importance of the corpus luteum in maintaining pregnancy was confirmed the same year by Bouin in France in histological studies of endometrial changes. He observed that, whenever a corpus luteum develops, the endometrium of the rabbit uterus undergoes progestational transformation to ready the uterus for the embryo. Later these same changes were produced with extracts from the corpus luteum.

Finally in 1928 Corner maintained pregnancies in spayed rabbits by means of such extracts. Progress was slow, however, until a bioassay technique, based upon the ability of progesterone to cause progestational transformation, was described in 1929. From 1930 to 1934 crystalline preparations of the hormone from the corpus luteum were produced in the United States and Germany, and in 1934 the generally accepted formula for progesterone was established. Recent work indicates that estrogen and progesterone are both essential for full differentiation of the endometrium. Progesterone apparently needs simultaneous action of estrogen, and also, less progesterone is needed to maintain pregnancy when given with estradiol than when given alone.

Although, as mentioned previously, there was some evidence prior to 1906 suggesting that the pituitary might be associated with sexual functions, it was not until a decade later that the gonadotrophic functions of the gland began to be understood. From 1916 to 1927 several workers demonstrated that removal of the pituitary gland caused atrophy of the gonads and that implants of the pituitary or injection of its extracts restored these atrophied glands to normal or stimulated normal ovaries. In 1931 and 1934 Fevold, Hisaw, and Leonard fractionated pituitary gonadotrophic extracts into fractions that were predominantly follicle stimulating (FSH) and luteinizing (LH) in action. FSH is largely responsible for development of germ cells, for in females it causes growth of follicles and in males induces spermatogenesis. When injected it is given subcutaneously or intramuscularly to produce a slow action. LH in the female causes developed follicles to rupture, ovulate, and form corpora lutea, and in males it chiefly stimulates the interstitial cells of the testis to elaborate testosterone, a male sex hormone or androgen. LH is injected into the female intravenously to facilitate rapid action. Gonadotrophins are complex proteins or protein-like compounds and are difficult substances with which to work. They have been highly purified, but they have not been prepared in pure form or synthesized. Highly purified FSH has been prepared during the last few years at the University of Wisconsin and at the University of California. Workers at California have also reported the preparation of highly purified LH. By use of these highly purified preparations in animal experiments, it has become apparent that FSH and LH are not independent in their physiological action, nor do they act at different times. Instead, they act simultaneously and in conjunction with each other in varying proportions. Their secretion is, however, under separate control by direct action of progesterone, estrogen, and androgen. The hormones involved in reproductive processes are, therefore, maintained in a delicate balance. This balance varies with different stages of the estrous cycle and is tied in with the adrenal, thyroid, and possibly other endocrine glands and is influenced by nutrition, light, temperature (latitude and season), and at times even by psychological factors, including the presence of a mate or the mating act itself. Most of the interactions in this complex picture are still not completely understood.

The complexity of endocrine actions in reproduction is increased by the fact that the placenta, at least in some species for certain, has been found to produce various hormones. In 1927 Aschheim and Zondek found a high concentration of estrogen and, a year later, of gonadotrophin (predominantly LH) in urine of pregnant women. In 1929 Cole and Hart demonstrated a potent gonadotrophin in pregnant mare serum (predominantly FSH). This hormone is not excreted in urine in any appreciable quantity and, therefore, when injected remains in the blood stream and acts for a prolonged period of time. Other gonadotrophins are excreted rapidly and must be injected at least once daily to be effective. It has been established that all of these hormones are elaborated mainly by the placenta. Furthermore, progesterone has been isolated from the human placenta, and there is some evidence that it is present in the placenta of the mare. The placenta supplements the normal sources of these hormones, or in some cases temporarily becomes the sole producer. This explains the ability of ovariectomized females of some species to maintain the fetus during advanced gestation. It is also known that the rat's pituitary produces little gonadotrophin during advanced pregnancy. The evidence indicates that there are great qualitative and quantitative differences in the hormone-producing ability of the placenta in different species.

Among the various hormones concerned directly with reproductive processes, there is still another produced by the anterior pituitary, namely, prolactin or luteotrophin. Its relationship to the gonads was first demonstrated in 1933, and it has been isolated in highly purified form. This hormone is responsible for maintenance of the corpus luteum and its secretion of progesterone during pregnancy and also for the initiation of lactation. Like the other hormones mentioned above, prolactin also may be produced by the placenta, for it has been obtained from that organ in the rat.

There is still one other hormone, oxytocin, that has been found to be involved in reproduction in the female. It is produced by the posterior lobe of the pituitary and was shown by Kamm in 1928 to be a separate hormone. He succeeded in separating the crude posterior pituitary extract, pituitrin, into vasopressor and oxytocic fractions. It was later found that these two principles are polypeptides. Du Vigneaud and associates isolated and then synthesized oxytocin in 1953, and for this accomplishment he received the Nobel price in 1955. This hormone stimulates smooth muscle in the female

reproductive tract and mammary gland. At mating time its secretion into the blood stream is a result of a nervous reflex initiated by the presence of, or service by, the male or by palpation via rectum of the female genitals. The reflex is blocked by adrenaline, the secretion of which can be stimulated by fear or excitement. The sensitivity of the uterus to oxytocin is most marked when under the influence of estrogen and least under progesterone. Oxytocin also is responsible for uterine contraction during parturition. Here the smooth muscle is sensitized by estrogen, but the trigger mechanism is still unknown. Other than the now known part played by estrogen and oxytocin in parturition, since 1906 little has been added to our knowledge concerning the mechanisms involved in parturition.

In the 1920's it was definitely established that testosterone is produced in the interstitial cells of the testis. Real progress in endocrinology of the testis was not made, however, until 1927. In that year the first unquestionably potent extract of testicular tissue was prepared by alcoholic extraction of bull testes at room temperature. Soon thereafter crystalline testosterone from bull testes was prepared in Holland. This hormone, like other androgens and also the naturally produced estrogens in the female, is a steroid.

Reproduction in the cow. An important milestone in the knowledge of bovine reproduction was the publication in 1927 of Hammond's book, *The Physiology of Reproduction in the Cow.* This book describes the results of extensive studies by him and also includes a review of literature. It contains much information concerning histology and anatomy of the reproductive organs and of time factors. The viewpoints concerning endocrines are interesting in light of the fact that most of the advances in endocrinology have been made since the book was written.

According to information now available, the functional hormone level of the cow is, in general, lower than that of other farm animals and is only about one-twentieth that of women. The FSH content of the pituitary is the lowest of any species studied. The LH content is also low, but the ratio of LH to FSH is higher than in the mare, sow, or ewe. On the other hand, the prolactin content of the pituitary is high. Cornell workers have found that only about 0.255 mg. stilbestrol injected daily for four days into spayed cows produces heat on the fourth day. In spite of daily injections, even at higher levels, estrus lasts in most cases less than one day. Such early termination of heat was explained by a block in the nervous system. This low threshold is reached before the follicle is ready to ovulate and may explain why the cow, of all mammals studied except the bat, ovulates after the end of estrus.

The Cornell workers have also suggested that the very low sex hormone thresholds in the bovine female may explain the occurrence of freemartins. These are female calves twinned with a male and with joined blood systems in the placentas. It is believed that the sex hormones from the male fetus override the hormones in the female fetus and cause her to acquire some of the genital characteristics of a male. This intermixing of the blood, and the resulting freemartins, occurs in about 90% of mixed-sex bovine twins. Such mixing of blood also occurs in many other species bearing two or more young, but females comparable to the freemartin are seldom born in other species.

Abortion and retained placenta have been associated with insufficient progesterone in the cow. Wisconsin workers found that, in cows with the corpus luteum removed before the 200th day of pregnancy, abortion occurred but could be prevented by 100 mg. progesterone daily. After the 200th day of pregnancy removal of corpora lutea or termination of progesterone therapy did not result in abortion in most cases. After parturition when progesterone therapy had been discontinued at least 25 days previously, placentas were usually retained. These results suggest that, if progesterone is required after 200 days, the placenta usually may not produce optimal amounts.

Large amounts of androgens are found in feces from cows, but not from bulls. There is evidence in other species that androgens play a role in various processes during the normal estrous cycle and also possibly in lactation.

Puberty, as measured by first detectable heat, is influenced markedly by nutrition. It was recently reported by Cornell workers that heat in heifers on a low plane of nutrition was first observed at 65 weeks of age; on a medium plane at 47.1 weeks; and on a high plane at 37.4 weeks. A Minnesota study showed that a ration low in phosphorus and protein delayed first estrus and repressed normal evidences of heat so that periods of estrus appeared to be missed. These different regimens caused no significant differences in breeding efficiencies, however.

Several independent studies have shown that normal estrous cycles of mature cows average 21 days, and of heifers, 20 days. The average length of estrus is 14 hours with 82% falling between 10 and 18 hours. Casida and associates were able to lengthen the cycle indefinitely by injecting 50 mg. of progesterone daily, starting on the fourteenth day of the cycle. Estrus occurred in most cases 4 to 6 days after termination of treatment. Other workers have since found that heifers bred at the first estrus after treatment have an abnormally low conception rate, although the results have been variable. There is no definite explanation of this reduced fertility. Another method of altering the length of the cycle and thus controlling time of estrus and ovulation is to squeeze the well-formed corpus luteum from the ovary. Ninety per cent of cows so treated come in heat 2 to 4 days

later. In a study in Denmark with a large number of cows, the conception rate from inseminations in the heat periods induced by this treatment were comparable to those in normal cycles. There is some danger, however, of hemorrhage and adhesions after squeezing the corpus luteum from the ovary.

Numerous workers have contributed to knowledge concerning the histology of the reproductive tract of the cow during all stages of the cycle and during pregnancy. These contributions include those by various Germans and a number by Americans during the last 25 years. Cole has shown that most of the large volumes of mucus secreted during estrus are produced by goblet cells in the epithelium in the portion of the vagina adjacent to and in the cervix. Not until the second day post-estrus do progestational changes in the endometrium begin to take place in preparation for receiving and maintaining the embryo. The uterine glandular epithelium thus formed begins retrogression on about the fifteenth day if pregnancy does not intervene.

In a study by Trimberger, blood on the external genitals after estrus was observed in 100% of cycles with heifers and 61% with cows. Of the animals where external blood was observed, it was usually seen on the second day. Work at Wisconsin has shown that this blood comes from the uterus as a result of varying degrees of hemorrhage. A common belief has been that occurrence of this bleeding is associated with failure of conception, but the data do not support this belief.

In the Fallopian tubes there are cilia throughout the full length. They probably play a part in the movement of the egg toward the uterus. There can be no direct muscular control of the infundibulum because it contains no muscle fibers. A mucus-like material is present in greatest quantities in the tubes during the third and fourth days after estrus.

Recent studies by VanDemark and Hays indicate that the smooth muscles of the cow uterus in vivo are equally active during all stages of the cycle, although the nature of the contractions vary. They and other workers have also found that the uterus was equally responsive to oxytocin throughout the cycle.

The solid material in the mucus of cows in estrus is mainly carbohydrate, possibly a mucopolysaccharide. During the middle of the cycle and during pregnancy some protein is present. Measurements in vivo indicate that the pH of the vagina usually varies between 6.5 and 7.5 with a slight drop at estrus for individual cows. English workers have devised a method of measuring the flow elasticity of vaginal mucus from the cow. The viscosity is least, and the flow elasticity greatest, during heat. The measurement of the latter property is a fairly accurate method of detecting estrus. Refinements in sampling the mucus and in measuring its flow properties have given promise of producing a technique for early diagnosis of pregnancy, for the mucus becomes extremely viscous during pregnancy. There appear to be slight cyclic changes during pregnancy, suggesting that there may be corresponding changes in levels of estrogen. Action by this hormone is associated with the low viscosity of the mucus at time of estrus.

In the ovary at 8 or 9 days post-estrus, the follicle for the next ovulation has reached almost the preovulation size of 14 to 15 mm. During heat the follicle attains a maximum size of 16 to 19 mm. After ovulation the development of luteal tissue inside the ruptured follicle begins immediately. Maximum size is reached at about the ninth to eleventh day of the cycle, when it comprises two-thirds to three-fourths of the ovary. It remains functional until the 15th to 20th day of the cycle and does not decrease appreciably in size until it is 20 to 30 days old but can be palpated through the rectal wall during two or three succeeding cycles. If pregnancy has taken place, the corpus luteum remains large until after parturition.

Most ovulations occur 13½ to 15½ hours after the end of estrus, with a range of 2 to 26 hours. The right ovary ovulates more frequently than the left. A study by Wisconsin workers in a large herd of Holstein cows showed that the incidence of "quiet" ovulations (ovulations without detectable heats) was 44.3% during the first 60 days and 11.0% during the 61 to 308 days postpartum. Most cows had detectable heats 46 to 60 days after calving. The over-all incidence of multiple ovulations was 13%, whereas that of twins born was only 1.92%, indicating a marked reduction in fertility with multiple ovulations. New Jersey workers found a relation between age and incidence of twinning. The rate increased until the sixth calving and then decreased. This trend parallels rate of twinning in humans and size of litters in litter-bearing mammals when compared at equivalent ages.

The complete mechanism causing ovulation is not known. As mentioned previously, LH acts directly on the follicle and causes its rupture and ovulation. The trigger mechanism causing the anterior pituitary to secrete LH in sufficient quantities is obscure. In the rabbit it is established that nervous reflexes, stimulated by sexual excitement and mediated through the hypothalamus of the brain, activate the anterior pituitary into secreting LH. The cow, on the other hand, ovulates spontaneously, that is, without sexual excitement. The ovulation process in the cow is not entirely independent of external nervous stimulation, however, for Wisconsin workers have shown that copulation during estrus by a sterile bull hastens the time of ovulation by an average of 2.2 hours, when compared with unmated controls. Workers at Cornell University have also shown that injection of atropine, a nerve-blocking drug, at the beginning of estrus delayed ovulation 24 to 66

hours whereas progesterone hastened ovulation. On the basis of this and other available evidence, Hansel has hypothesized that the combined action of estrogen and progesterone stimulates release of LH. Their action is mediated, at least to a large extent, through the hypothalamus. The fact that Edgar found progesterone in the follicle of the cow prior to ovulation supports this hypothesis. The mode of action of LH in causing ovulation after it reaches the follicle is obscure.

Careful studies conducted at Nebraska and elsewhere indicate that, to obtain maximum fertility, cows should be inseminated during the last half of estrus. In artificial insemination under field conditions, the usual recommendation is to breed in the afternoon the cows first noticed in heat in the morning, and in the morning those first noticed in the previous afternoon.

By fixing and sectioning oviducts of cows, Gerasimova and associates found that ova are fertilized in that section of the oviduct 8 to 9 cm. from the infundibulum. At first, passage of ova down the oviduct is rapid, and later slower. During the first 6 hours after ovulation the ova pass through the infundibulum and one-third of the way down the oviduct. After 96 hours they pass into the uterus. Of all bovine twins, about 6% are identical. That is, both are formed from a single developing egg, which splits into two parts. The allanto-chorion (afterbirth) develops rapidly and by the fifth week fills both horns of the uterus.

There is not a definite implantation by the embryo in the uterine wall. Instead, there is a gradual interlocking between the chorion and the three or four cotyledons immediately surrounding the embryo. It is, therefore, difficult to establish precisely the time of firm attachment, but it appears to be about 36 days after ovulation. The embryo probably is then beginning to receive nourishment through the cotyledons. Since the early paper by Assheton in 1906, many workers have studied the embryonic development, placenta, and uterine milk of the bovine. More recently histochemical techniques have been employed. There are, nevertheless, still many gaps in knowledge of this field which need to be filled. One item of interest, however, is a recent report from England concerning the influence of the size of the mother upon the size of offspring as determined by reciprocal crosses between the South Devon and Dexter breeds. The latter is one-half the size of the Devon. The size of calves born was in proportion to the size of the mothers. The limiting factor appeared to be the size of the uterus.

During the last several years enough data have been accumulated from various sources concerning the gestation length of dairy cows to enable the establishment of "norms" for individual breeds. It is also well established that bull calves are carried a longer time than heifer calves.

Embryonic mortality has been shown during the last decade to be an important factor in over-all fertility of dairy cattle and in the occurrence of missed estrous periods or of estrus after a period during which a cow was believed to have been pregnant. These shorter abnormal intervals without heat take place because of resorptions, longer ones by abortion. Casida and his students have been able to partition the causes of infertility in cows. Their data indicate that 85.9% of ova shed are fertilized; the embryonic death rate, estimated as the per cent of fertilized ova that die, is 21; and 40% of all potential young (all ova shed) in dairy cattle are lost by 60 to 90 days after breeding. They estimated that of this 40% loss, three percentage units are due to anatomical abnormalities in the cow, nine to defective ova, 12 to failure of fertilization resulting from undetermined causes, and 16 to death of the embryo. At least part of this loss is caused by abnormal ova or spermatozoa or by physiological deficiencies in the cow's reproductive tract. The characterization and remedying of these physiological deficiencies is one of the most fertile fields for future research. Complete elimination of embryonic mortality probably never can be accomplished, and probably we would not want to do so. It has been suggested that embryonic mortality and abortion, especially in humans, are often blessings in disguise, for they may prevent the birth of most live monsters or young with physiological deficiencies.

After parturition, a period of about 47 days is required for the uterus to return to normal size, as determined by Wisconsin workers by manual palpation through the rectum. The interval for first-calf heifers was 42 days and for older cows, 50 days. Workers at Illinois studied the reproductive tracts of cows killed at various intervals after parturition. Until 50 days after calving there was considerable blood and swelling in the uteri, and it was concluded on the basis of these observations that conception would be unlikely during this period. Two field studies have corroborated these observations. Fertility level increased with increase in postpartum interval to 90 days. The resulting recommendation has been that cows not be bred until at least 60 to 80 days after calving even though they will come in heat earlier.

Superovulation and egg transplantation. During the last decade considerable attention has been given to the problem of superovulation and egg transplantation, especially in the bovine. Superovulation is the administration of FSH and of LH to produce many eggs at one time. Egg transplantation is the transfer of these eggs to another female, the recipient. The thought has been that an outstanding cow could be superovulated, the eggs transplanted to ordinary recipients (one per recipient), and numer-

ous offspring thus obtained from the outstanding cow. Only three calves have been produced in this way. The procedure included killing the donor, flushing the eggs from the excised reproductive tract, and placing them in the uterus of the recipient by means of surgery. This procedure is the only successful one so far, for several reasons. It has been difficult to obtain eggs from the living animal, although workers at Minnesota are now having some success. It has also been demonstrated that introducing eggs into the uterus of the recipient via the cervix, as one deposits semen in artificial insemination, introduces infection. In order to have ova survive in the uterus, they must be placed there when it is under the influence of progesterone. The uterus is, during that time, highly susceptible to infection by bacteria, which can be carried in with the egg and instruments. On the other hand, when the uterus is under the influence of estrogen it is resistant to infection, but, as stated above, eggs would not survive in such an environment. There is a possibility that inclusion of antibacterial agents, such as sulfanilamide and streptomycin, in the medium with the egg when it is introduced into the progestational uterus, may overcome the infection. Another problem has been the reduction in response to gonadotrophins with repeated superovulations, but the Minnesota workers have recently been able to superovulate cows repeatedly without such refractoriness.

Another posssible application of egg transplantation would be the shortening of the generation interval. If young could be produced by transferring eggs from calves to mature recipients and thus have the latter carry the calves during pregnancy, one generation could be obtained each year. With such a technique more rapid gains in animal breeding could be obtained than are now possible where at least 2½ to 3 years is required per generation. For example, with the technique described above, in 3 years a cattle breeder could have a calf whose sires were all well proven, or whose sire was the same, for three generations. Successful superovulation of calves has been accomplished by superovulating once and again after 3 weeks. Ovulations were not procurable with the first treatment but were with the second, owing apparently to the formation of luteal tissue from the first treatment. The apparent necessity of luteal tissue for ovulation is additional evidence that progesterone plays a role in this phenomenon. No success has yet been attained in fertilizing eggs in the calf.

Superovulation when perfected will be a valuable tool for the geneticist, the physiologist, and the animal breeder.

Artificial insemination. Mass breeding of cows by artificial insemination was first developed by the Russians. Their first venture on a large scale, described by Milovanov, was in 1931. In that year, 19,800 cows were bred, with an average of only 100 cows per bull. Semen was collected with a sponge and diluted 1:2 with a medium containing glucose, a phosphate buffer, and sodium sulfate. A maximum of 5 cc. of diluted semen was used for each insemination, which was performed with a speculum and ebonite catheter. The Russians concluded, after their first year's operation, that the working radius from a center should not be over 3 to 5 kilometers and that the number of cows per center should be considerably less than 3,000. Milovanov stated that the year 1931 marked the end of the experimental stage in artificial insemination of cows and its beginning as a "powerful zootechnical tool." Thenceforth, according to Milovanov, the objective of the method was the utilization of spermatozoa from the best sires on the largest possible number of animals. Its other uses, prevention of disease and control of sterility, became of secondary importance.

In a few years the Russians learned that many spermatozoa were injured by rapid cooling and that volume of semen per insemination could be reduced. One of their main problems, however, was the collection of semen from the bull. In the beginning the insertion of a sponge into the vagina of the cow was the method of choice. After squeezing out the semen, from 25 to 99% of the spermatozoa were retained in the sponge, depending upon saturation and the volume of the ejaculate. Some bulls were sensitive to it, and a special room was required for cleaning, disinfecting, and drying the sponge. Large numbers of spermatozoa were damaged, and spread of disease from cow to bull was highly possible. Finally, the artificial vagina was found to be far superior to other methods.

Credit for the invention of the artificial vagina must be given to an Italian, Amantea. This device is probably the greatest single contribution to artificial insemination. It enabled the procuring of the full ejaculate free from contamination with secretions or possible infection from the vagina of the cow.

In 1936 the first artificial breeding cooperative in the world was organized in Denmark. Veterinarians who did the breeding there developed the so-called rectal method of inseminating cows. With this method the inseminating tube is guided deeply into the cervix or into the uterus by the hand in the rectum. By thus placing semen closer to the ovary, fewer spermatozoa are needed than if semen is deposited in the vagina.

Enos Perry visited one of the cooperatives in Denmark, saw its possibilities, and in 1938 organized in New Jersey the first cooperative in the United States. It would be well to mention, however, that artificial insemination of cows was being practiced in a few herds in the United States at that time.

One of the most important contributions to the industry was the yolk-phosphate diluter by Paul Phillips. Spermatozoa retain motility and

fertility much longer in this than in the Russian diluters previously employed.

Methods of counting spermatozoa by means of a photoelectric colorimeter have been found to be a quick and accurate means of determining number of spermatozoa per cubic centimeter of semen.

Salisbury and his students found that the number of spermatozoa per insemination could be reduced to twelve million (average dilution 1:100) without reducing fertility. This discovery increased greatly the number of cows that could be bred to each bull and enabled the continued expansion of the industry without concomitant "dilution" of bulls and without increase in cost to the farmer in spite of monetary inflation. If there were no semen waste, it would be possible to breed over 400 cows with each ejaculate.

Another development in the industry has been the finding by workers at Cornell and Pennsylvania that antibacterial agents (sulfanilamide, streptomycin, and penicillin) increase fertility of semen and reduce embryonic mortality in cows bred. Fertility of semen in bull studs is measured by percentage of cows not returning for a repeat service after a given period of time—nonreturn rate. The decline in fertility, when measured at, say, 28 to 35 days after service and when measured again at 60 to 90 days after service, is caused in part by embryonic mortality. The reduction in this decline has been brought about by the control of pathogenic bacteria in semen, most of which are ejaculated with the semen and are venereal in nature.

A discovery that holds promise of completely revolutionizing the artificial breeding industry was the accidental discovery in England in 1949 that glycerol enables preservation of spermatozoa by freezing. The chief advantages of frozen semen are: *(a)* Spermatozoa can be preserved for long periods of time, if not indefinitely. The longest time that liquid semen can be held for breeding cows and still maintain good nonreturn rates is 2 or 3 days. *(b)* Practically all waste of semen can be eliminated. With present methods two or three times the volume of semen actually inseminated is shipped to technicians daily to insure their having sufficient for their fullest days. *(c)* Dairymen can have a wide choice of sires not possible with liquid semen. *(d)* Cows can be bred with spermatozoa from sires after their death. *(e)* Semen can be shipped any distance desired.

The technique of freezing semen is still not perfected, however. From one-quarter to one-half of the spermatozoa are killed in the process. Another disadvantage at the present time is that the cost of processing, storing, and transporting frozen semen is higher than for liquid semen. When semen is once frozen, it must be kept at –75° C. or lower at all times. This is accomplished by means of solid carbon dioxide or by electrical refrigeration. With perfection of the technique of freezing semen, the artificial breeding industry will be able to attain in full Milovanov's objective, the utilization of spermatozoa from the best sires on the largest possible number of animals. Another chief problem remaining is the development of methods enabling the accurate selection of sires with the greatest ability to transmit high milk production to their offspring. This is a problem for the geneticist and is an important one when each bull will sire so many offspring.

No other practice has been received with such favor by dairymen in this country as has artificial insemination. The main research contributions responsible for its rapid growth and progress have been mentioned above. Many other lesser contributions of research, when added together, are important. Stud operators and technicians in the field have acquired proficiency in their duties. The farmer, himself, also shares credit for the gains made. He has learned the importance of breeding cows at the optimum time and has made it possible for the field technician to do so.

As a result, artificial insemination has made rapid progress in this country. This progress is demonstrated statistically in Table 1. It can be seen that over 20% of the cows are now bred artificially. This is a large number, but over 40% of the cows in England and close to 80% in Denmark are bred artificially. In the table it is shown that, in 1955, an average of 2,210 cows were bred per bull in all studs in the country. This number is large as compared with 50, the number which a bull can ordinarily breed per year by natural service. Nevertheless, as shown in the table, in one stud a comparable figure for 1955 was 8,579 cows. Even this can be improved upon by increasing efficiency of the use of liquid semen in the field. Furthermore, an average figure of 50,000 or more is attainable with frozen semen. Finally, in the table are given nonreturn rates (60- to 90-days after service) by years for one bull stud. The increase from 52% in 1940 to 72% in 1954 is attributable to all the factors listed above that may influence effectiveness of breeding by artificial insemination. The jump from 61% in 1948 to 72% in 1949 can be credited to a number of factors, including management. The most important one is the addition of antibiotics to diluted semen. The high fertility level of 70% or over exceeds that experienced with natural breeding.

From the standpoint of the physiologist interested in reproduction of dairy cattle, the artificial vagina and the expansion of the artificial breeding industry have provided research tools of the greatest value. With the artificial vagina, as mentioned previously, the full ejaculate of semen can be procured uncontaminated with secretions or microbial organisms from the vagina of the cow. The scientist can now, therefore, study spermatozoa in vitro and learn much about their physiology and morphology and

TABLE 1

Data showing yearly progress in artificial insemination in United States. Numbers and percentages of cows bred by artificial insemination, cows bred per bull, and nonreturn rates in one stud

Year	Cows bred by artificial insemination		Cows bred per bull		Nonreturn rates in one stud[c]
	Number[a]	Of all cows	All studs[a]	In one stud[b]	
		(%)	(No.)	(No.)	(%)
1939	7,539	0.03	228		
1940	33,977	0.14	246		52
1941	70,751	0.28	299	143	57
1942	112,788	0.43	274	187	60
1943	182,524	0.67	318	224	57
1944	218,070	0.79	332	274	59
1945	360,732	1.3	495	901	59
1946	537,376	2.0	597	2,668	62
1947	1,184,168	4.6	815	2,651	60
1948	1,713,581	7.0	982	2,526	61
1949	2,091,175	8.8	1,078	3,526	72
1950	2,619,555	11.0	1,245	4,986	72
1951	3,509,573	14.8	1,605	6,645	72
1952	4,295,243	18.4	1,848	4,177	73
1953	4,845,222	20.1	1,865	4,877	72
1954	5,155,240	20.9	1,937	6,847	72
1955	5,413,874	23.1	2,210	8,579	

[a] From Dairy Herd Improvement Assoc. Letter, USDA, March, 1956. Prior to 1946 cows were reported only on basis of enrollment.

[b] Cows (first services) bred per bull-year in studs of American Breeders Service.

[c] Sixty- to 90-day nonreturn rates in New York Artificial Breeder's Coop., supplied through courtesy of Maurice Johnson. Figures given are for fiscal years beginning on June 1 of year indicated.

can explore the chemical, physical, and microbial characteristics of their natural medium, the seminal plasma. He can now measure the reproductive capacity of bulls and study the many factors that influence it. In addition, the scientist has a means of measuring the fertility of spermatozoa by the breeding of cows. Each ejaculate (or portions of an ejaculate given different treatments) is employed in the breeding of a sufficient number of cows to enable characterization of its fertility. With these tools at his disposal, the scientist has made progress in the physiology of reproduction of the bull not thought possible before the advent of modern artificial breeding. This progress has gone hand in hand with the development of the industry and has been a major factor in its progress, as indicated above.

Reproduction in the bull. Formation of spermatocytes in the testis begins when the bull is about 63 days af age. At 224 days spermatozoa are present in many tubules, and at 15 months in all tubules. They remain viable for over two months in an epididymis isolated from the testis. In normal bulls rate of spermatogenesis apparently can not be increased by administration of hormone. There is some indication, however, that gonadotrophins can do so if a deficiency of the hormone is the cause of reduced spermatogenesis. Spermatozoa in the male tract are immotile, and when flushed out with a saline solution require considerable aeration before displaying movement. When ejaculated, however, they display full motility immediately. Lardy and Ghosh found that there is a "metabolic regulator" in spermatozoa which stimulates the metabolic activity of the cells and causes a reduction in efficiency of utilization of energy. Apparently an enzyme present in the accessory secretions liberates the activator. For this reason, ejaculated spermatozoa have a greater rate of metabolism and utilize energy less efficiently than do epididymal spermatozoa. This regulator is hydrogen sulfide, cysteine, or some other similar compound containing sulfur.

Erection of the penis and ejaculation are mediated mainly through the autonomic nervous system as is heart action. They can be elicited by rhythmic electrical stimulation with an electrode inserted in the rectum. This fact has been the basis of new devices designed to obtain semen from bulls by electrical stimulation.

The volume of semen and number of spermatozoa in natural ejaculation are influenced by psychic factors. Sexual excitement results in production in the first ejaculate of spermatozoa in larger numbers and of better viability and fertility than if no excitement had taken place. Such excitement can be produced by having a bull mount a cow while an attendant holds the sheath to one side to prevent coitus, having the bull dismount, and then letting him mount and ejaculate. Pennsylvania workers have also demonstrated that the bull's libido is influenced by the "attractiveness" to him of the cow he mounts. Some cows are inherently more attractive than others, and a new one can be more desirable than one with which the bull is more familiar. The reason for the appar-

ent improvement in quality of semen with adequate excitement needs elucidation. Thus, a beginning has been made in the study of bull behavior, and practical results have already been procured which are helpful in the handling of the bull at time of collection of semen.

Other phases of bull management have been studied, including frequency of collection of semen. It is important to learn the optimum frequency in order that the maximum amount of spermatozoa can be obtained over a long period of time. The evidence indicates that one or two ejaculates per week do not procure all the spermatozoa that are produced, but on the other hand, too frequent collection may reduce the bull's willingness to mount and ejaculate.

The naturally occurring sugar in semen is fructose, not glucose, as formerly thought. It is the chief source in semen of metabolizable energy for spermatozoa. The level of fructose in semen is related directly to the capacity of the accessory organs to produce this sugar. This capacity, in turn, depends upon the degree of testosterone production in the testes. By means of this relationship it has been learned that testosterone is produced considerably earlier than are spermatozoa in the testes of the immature bull.

No laboratory method has yet been found that enables accurate prediction of fertility of spermatozoa, although many tests have been devised. These include spermatozoan motility, methylene blue reduction time, resistance to temperature shock, stains which color dead spermatozoa but not live ones, oxygen uptake, viability at 5°, 38°, or 45° C., resistance to hypertonic solutions of sodium chloride, change in pH during incubation at 38° C., and others. It appears as though the possibility of finding one or a combination of tests that will enable prediction of fertility of a bull by testing several samples is better than the possibility of being able to predict fertility of individual samples.

Improvement of diluters has been given considerable attention. Milk or skimmilk, heated, holds promise of having some advantages over yolk-citrate. Missouri workers have found that the factor in yolk which has been so beneficial for livability of spermatozoa in vitro is a lipoprotein. This substance increases resistance of spermatozoa to temperature shock.

Biochemists have studied various phases of spermatozoan metabolism. Fructose is the chief natural source of energy for spermatozoa, but they are able to metabolize phospholipids, glucose, and other compounds.

With aging or exposure to detergents, the lipoid capsule, which surrounds the spermatozoa, is apparently altered. The cell wall becomes more permeable, as indicated by loss into the medium of cytochrome *c* and by metabolic changes.

New chemical and physical techniques are enabling the study of minute details of spermatozoa. With cytochemical methods researchers have determined the location in the cell of minute amounts of elements and compounds and have studied relation of such findings to functional activities of the cells. The microspectrophotometer has permitted quantitative analyses of constituents within the intact cell. Considerable information concerning structure has been procured with the electron microscope.

With natural service the spermatozoa are deposited in the vagina in the vicinity of the cervix because the highly convoluted structure of the cow's cervix prevents passage of the penis through it. VanDemark and Hays recently found that spermatozoa are transported in the genital tract of the cow very rapidly, live spermatozoa reaching the ovary in 2.5 minutes and dead spermatozoa in 4.3 minutes or less. This occurred with either natural or artificial breeding. Evidence indicates that peristaltic contractions throughout the tract are responsible for this rapid travel. That such rapid travel enhances fertility is yet to be established definitely.

It has been shown in rabbits and rats that spermatozoa require a sojourn of about 5 hours in the female tract before they are capable of fertilizing ova. Whether such a period is required by bovine spermatozoa has yet to be determined. Furthermore, a fairly good conception rate can be obtained in cows when they are inseminated 24 hours or more before ovulation. Thus, spermatozoa retain their fertility in the cow for that length of time.

Light and temperature. It has been known for many years that some mammalian species, such as deer, sheep, and ferrets, have definite breeding seasons and that this seasonality can be influenced by light and temperature. Until recently it was supposed that the bovine was in large part independent of such influences. Evidence gathered by several workers has, however, demonstrated seasonal changes in fertility in cows in both northern and southern states. In northern states and lower Canada the lowest fertility levels were during winter. Studies by Cornell workers indicated that hours of daylight were more important than temperature. This finding was supported by observations made in Alaska which indicated that fertility of cows is markedly reduced during the extremely long winter nights in the far north. On the other hand, in Louisiana reduced fertility occurs during the summer months and is attributed to heat. The effect appears to be more marked among bulls than among cows. At the University of North Carolina bulls have been exposed to continuous high temperature, or to short periods of high temperature at monthly intervals, in rooms where temperature and humidity could be controlled. In both cases the high temperature impaired spermatozoan production.

The testes require a temperature lower than that of the body for normal functions, and this is the reason for their hanging suspended from the body. The tunica dartos muscle, which forms a thin membranous layer beneath the skin of the scrotum, acts as a thermoregulator and relaxes the scrotum when warm and holds it close to the body when cold. It has been demonstrated that covering the scrotum with insulating material, and thus preventing its being cooled by the air, will inhibit spermatogenesis in the testes. The production of testosterone by the interstitial cells is not reduced by such treatment, however, and this treatment was one of the methods used to establish that these cells were the producers of the male sex hormone.

Remarks and Predictions

Many lessons can be learned from the story of the growth of knowledge of reproductive phenomena from its beginnings centuries ago to today. Two important ones that merit emphasis are:

(a) The value of fundamental research. Without the great background of knowledge contributed by workers searching for truth for its own sake, knowledge concerning reproduction of the bovine would not have progressed far beyond what was known in the days of Aristotle. For the benefit of the next generation, modern science should be "planting a tree for every one cut" in the form of new fundamental knowledge.

(b) The value of laboratory animals. Work with rabbits, guinea pigs, rats, and mice has given much information that has been invaluable in research with the bovine. The modern researcher studying problems in the cow or bull can gain much information and acquire many skills and facts in preliminary work with small animals, and at less cost than with the large ruminant.

In regard to predictions for the next 50 years, any that might be made must be projected from what is already known. Beyond the horizons there must be developments about which we can not even dream.

A few problems that will very likely be solved, or about which our knowledge will be at least broadened, will include the interactions of hormones associated with reproductive processes and the manner in which the hormones act to bring about the metabolic changes at the points where they work. Compounds with gonadotrophic activity will be synthesized. New hormones may be discovered.

Freezing of spermatozoa will be perfected so that there will be no loss of viable spermatozoa during the process as there is now. However, ways may be found to maintain fertility of spermatozoa for long periods at room or refrigeration temperature by freeze-drying or by chemical means. Fertilized and unfertilized ova will also be preserved for prolonged periods with methods similar to those now employed or proposed for spermatozoa. In vitro fertilization of bovine ova will be accomplished and will be a useful tool for the physiologist.

In light of the present accomplishments in work with other species and in the development of various techniques, it is within the realm of possibility that bulls may be completely eliminated. To accomplish this, choice bulls of the land would be selected. From them spermatogonia will be removed and cultured in vitro. In the testis spermatozoa are formed in the following steps in order: spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids, and spermatozoa. The spermatogonia serve as mother cells and continually produce the primary spermatocytes. From the original cultures of spermatogonia which have been obtained from bulls, spermatozoa will be removed as formed, and the spermatogonia will be left behind to continue production of more spermatozoa. Mass production methods could be employed. Perhaps selective irradiation or other methods could be developed to eliminate all male-producing cells.

Each secondary spermatocyte contains one-half as many chromosomes as the primary spermatocyte or spermatogonia and is, therefore, capable of developing into either a male- or a female-producing spermatozoon. Possibly ways will be found to cause these secondary spermatocytes to reproduce themselves by cell division. If so, cultures could be started from individual secondary spermatocytes, and cytological evidence could determine which would produce females and which males. These cultures producing males would be eliminated, and all spermatozoa thenceforth produced would beget heifers.

Culturing in vitro of spermatogonia or spermatocytes may provide new methods for the geneticist to improve productivity of dairy cattle. He may be able to irradiate small areas on chromosomes with devices now available and produce mutations. By trial and error the genes responsible for milk production could be located. Then additional irradiation could mutate these genes at will.

Continued or accelerated progress will be made in the future if the following conditions for research are maintained: *(a)* Freedom of self-expression and communication of thoughts and ideas, including the ability to transmit ideas and criticisms up "lines of command" as well as down. *(b)* Reward to the research worker in accordance with his abilities and efforts. *(c)* Time to garner necessary facts before conclusions are drawn. *(d)* Freedom to search into promising or interesting avenues and byways. *(e)* Support of fundamental as well as

applied research. *(f)* Contact with stimulating colleagues.

If such a "climate" for research is maintained, the words of David Sarnoff will apply: "There is no longer margin for doubt that whatever the mind of man visualizes, the genius of modern science can turn into fact."

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Dairy Cattle Breed Associations

L. W. Morley

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Cattle are not native to North America. Some were brought to what is now the United States by the early settlers. Historical references to cattle coming to the early colonies are more and more frequent from 1535 on. These imported animals and their descendants came to be generally known as "native cattle" and in 1860 they totaled 8,500,000. Starting about 1860-1865 there developed considerable interest in improved breeds of cattle. "Purebreds" were imported from Holland, the Channel Islands, Scotland, and Switzerland in increasing numbers during the last half of the 19th century.

L. W. Morley

Individual owners kept their own herds and breeding records. It became increasingly apparent, to those interested, that a central agency for keeping these records was most desirable.

Organization of Breed Associations

In the early days most of the improved cattle were owned by men of means and social standing. The men who founded the breed associations thought of them more as social organizations formed for the business of keeping and preserving records and the promotion of an individual breed. Thus, two of these organizations had from their beginning, and still retain, the word "club" as a part of their official name.

The formation of a breed association followed a fairly uniform pattern. At first community, county, or state organizations were formed, which later united to form a national organization. In other instances, regional organizations, set up without reference to geographical, political, county, or state lines, later united to help form national associations.

The breed associations came into being as national organizations on the following dates:

The Ayrshire Breeders' Association	1875
The American Jersey Cattle Club	1868
The Brown Swiss Cattle Breeders' Association of America	1880
The American Guernsey Cattle Club	1877
The Holstein-Friesian Association of America	1885

Although the objectives were stated with some variation, the purposes of each were to keep the records, maintain the herd books, and improve and promote the best interest of its particular breed.

Keeping the records consisted of keeping in permanent form the name and number of each registered animal and the breeding date, birth date, name, and number of each registered progeny. These records were put in permanent form through the publication of "herd books," which were distributed to breeders, pedigree makers, and educational institutions and, more particularly, the Land Grant colleges.

Owners were interested in both production and conformation. In early days, the only means of determining production was to weigh each milking for a given period, churn the cream, then weigh the resulting butter. This procedure was difficult enough for a 7-day period and even more difficult and expensive for a 30-day or longer period. Then too, the amount of fat in a given number of pounds of butter differed, depending on how the cream and resulting butter were handled. In other words, the butter varied in salt, moisture, and curd content. This weigh-and-churn method was, however, the most practical way of determining fat production prior to the development of the Babcock test in 1892.

Production testing. Some of the breed associations early set up departments to conduct official tests on animals. Many difficulties developed, however. Instances occurred in which it became evident that the public did not have full confidence in these production records. In 1894 the cooperation of the several agricultural experiment stations was secured to act as neutral agents in seeing that the tests were honestly and accurately conducted.

Each association set up classes or divisions in which production data were recorded. These data included the age of the animal, the length of the test, and the number of days the female carried a calf while on test.

Conformation. Each breed association early adopted a score card with numerical points to describe the ideal animal of its particular breed. Shows and exhibitions were, however, more influential in designating desirable type than were printed score cards.

Relationships with the American Dairy Science Association

Fifty years ago, when the American Dairy Science Association was organized, five breed associations were in existence. From the earliest days of their organization there has been a high degree of cooperation between the breed associations and the Land Grant colleges. The formation of the American Dairy Science Association gave impetus to greater cooperation in

many ways, one of the most significant of these being the adoption by A.D.S.A. of uniform production testing procedures for all official tests that were supervised by the experiment stations.

The Purebred Dairy Cattle Association

The Purebred Dairy Cattle Association was formed in 1940 by representatives of the different breed associations. Its objectives were to work toward uniformity in the classification of test designations of the breeds and a unified dairy score card. Until that time each breed had its own score card which described its ideal animal. These varied considerably among breeds. The Purebred Dairy Cattle Association working closely with the A.D.S.A. has rendered outstanding service in this field, and its accomplishments have been greatly appreciated by breeders everywhere.

Herd Testing

There was, rather early, realization that the 7- and 30-day tests left much to be desired. It was possible by allowing a cow to be dry for an abnormally long period and having her excessively fat at the time of freshening to obtain a production of milk fat that did not have a close relationship to the yearly production of the animal.

The dairy farmer and breeder became more and more interested in the annual production of his entire herd rather than in the amount which the selected individual animal could produce in 7 or 30 days under most favorable conditions. The Ayrshire Breeders Association in 1925 was first to establish the 305-day, twice-a-day milking herd test. The other breed associations followed within a few years, each establishing its own herd testing rules.

There were variations in the rules as to what constituted the "herd" and as to exemptions of individual animals. However, in the past few years there has been a marked advance in the uniformity of herd testing rules among the various associations.

Most of the associations never did officially discontinue the 7- and 30-day tests, but they were finally discontinued because of lack of interest in them. The individual long-time tests are constantly becoming fewer as compared with the number of cows on "Herd Test."

Appreciation of Dairy Sires

The value of the herd sire in propagating both production and type has long been understood. However, the evaluation of sires for both production and type has come to be more on the performance of all daughters or a large number of daughters, rather than a selected few.

The principal manner of type promotion in earlier days was through the show ring at county, state, regional, and national shows and exhibitions. These events, although serving a useful purpose, left much to be desired. The winning of a blue ribbon in a class of three or four animals was far different from winning a blue ribbon in a class of 15 or 20 animals.

It has been customary for all associations to give trophies, cash prizes, and ribbons for the winning animals of their respective breeds at the principal dairy shows. However, the amount of money appropriated in recent years for these activities has been considerably less than formerly.

Classification

Breeders long felt that some system was desirable whereby the type of animals shown could be evaluated by a competent judge and this information made available to all who were interested. If a breeder was interested in the purchase of an animal from a distant herd, he could study the production records of this herd and get a general idea of the probable producing ability of the animal in question. But in the matter of type, he had nothing comparable to production records on herds that had never been shown.

The Holstein-Friesian Association established January 1, 1929, a system of herd classification. The other associations adopted classification systems as follows: Jersey in 1932, Ayrshire in 1942, Brown Swiss in 1943, and Guernsey in 1947.

The classification systems varied somewhat, though there has been a marked tendency toward uniformity. In classification, a trained judge of dairy conformation goes to the farm and, using the score card as a guide, gives each animal in the milking herd a designation according to its confirmation, the designation terms used being excellent, very good, good plus, good, fair, and poor. The classifiers are designated by the breed associations and are more often than not cattle specialists from the dairy departments of the Land Grant colleges.

The fact that classification has constantly increased and that classification designations are increasingly used in educational, pedigree, and publicity work is sufficient proof of the value of this activity.

Artificial Insemination

Properly speaking, artificial insemination is not a project of the breed associations. When the artificial insemination work for the improvement of dairy cattle was first organized, it was doubted by many breed association officials whether offspring from artificially inseminated registered females could be registered. There was, however, a realization by the breed associations of the desirability of such registrations and a willingness on the part of breed association officials and the officials of artificial breeding establishments to work out rules and

procedures for such registrations. The year after year increase in the registration of animals from artificial insemination has been phenomenal. One breed association, reporting for the year 1954-55, states that registrations from artificial insemination increased from 9.3% in 1948-49 to 28.1% for 1954-55.

The fact that approximately 30% of all animals registered by the dairy breed associations in 1954-55 resulted from artificial insemination eloquently attests to the value of this cooperative activity.

Promotional or Extension Activities

Persuading more people to own and breed animals of its own breed has always been one of the most important activities of the breed association. This has been done through use of many well known activities, but most association officials feel that publicizing production records has been the most important method.

The breed organizations have employed fieldmen or extension representatives for many years. These people work closely with local and state breed organizations and with county agents, teachers of vocational agriculture, and other individuals and organizations where cooperative effort is mutually advantageous. Promotional activity has for years taken a considerable share of each association's budget dollars.

Finances

Breed associations are financed by initiation fee for life membership (these fees have varied in the last 50 years from $25.00 to $100.00 between associations), registration fees, transfer fees, production testing fees, classification fees, pedigree fees, and income from miscellaneous items and activities.

Breed Milk

At least four of the breed associations have from time to time been interested in a designated or trade-marked breed milk. The Ayrshire "Soft Curd," the Holstein "White Nectar," the Jersey "Jersey Creamline," recently changed to "All Jersey," and the Guernsey "Golden Guernsey" are examples. The promotional value of a breed trade-marked milk has been in the past, and still is, a debatable question.

Influence of Purebreds

Although registered purebreds have never exceeded 5% in numbers of our dairy herd population, their influence in the improvement of the average production of dairy animals is inestimable. Generally speaking, improved production has come from purebred sires. It was early recognized that not all registered bulls actually improve the production of their daughters over that of the dams, nor is the production of purebred daughters always greater than that of their dams.

The work of the breed associations in keeping the identity records of its animals, in production record testing, in improving conformation, and in the stimulation of ideals and love for better cattle has been one of the most important basic factors in the development of a great dairy industry in the past 50 years.

Purebreds will continue to be the foundation for future improvement of dairy animals.

Climatic Physiology of Cattle[1]

SAMUEL BRODY

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Many factors contribute to the interest in climatic physiology of cattle. They include development of revolutionary transportation methods enabling selection and breeding of cattle on a global scale in different climates; demands for cattle-shelter specifications for widely differing climates; diplomatic and humanitarian desire to improve the nutritional condition of the undernourished millions. Milk is the least expensive dietary supplement (rich in limiting amino acids, calcium, and vitamin B_{12}) to the unbalanced diet of malnourished peoples who live mostly on dietary-incomplete foods of plant origin. Unfortunately, most of these people inhabit high-temperature regions, which are unfavorable for dissipating the heat increment of lactation (Figures 1a and b).

Samuel Brody

Owing to space limitations and to the recent excellent documented reviews on this subject by Wright, Findlay, and Yeates in Hammond's *Progress in the Physiology of Farm Animals*, no attempt is here made to review the literature. The charts and tables are taken from, or are based on, the data obtained in an extended study by the cooperative Climatic Laboratory group[2] at the University of Missouri. Details of this work are given in the Missouri bulletins on *Environmental Physiology and Shelter Engineering*.[3] This paper presents an integration of some of the data in 36 bulletins by a discussion of the situation as a whole, including a comparative analysis of the relative reactions of three categories of cattle (European, Indian, Santa Gertrudis) and also man to different temperatures.

Relative Heat- and Cold-Tolerance of Cattle

Some animals, like the long-haired yak cattle of Tibet and Western China and the wooly cattle of the Scottish Highlands, are very cold-tolerant. They are essentially arctic species as tolerant to cold as the caribou and reindeer.

But even the less hairy European-evolved cattle are very cold-tolerant. D. Brown (1953) of the Wyoming Experiment Station wintered dairy calves outdoors with access to an open shed 20 feet deep. During a sudden temperature drop from +40° to −60° F. the calves in the open shed humped and shivered, but, after 36 hours of continued cold, they seemed normal and there were no frozen feet or ears!

In contrast to the cold-tolerant and heat-intolerant European-evolved cattle are the heat-tolerant and relatively cold-intolerant Indian-evolved cattle called Zebu or Brahman.

The relative cold tolerance of European and Indian cattle is indicated by the observation that at 7° F., the increase in heat production in Holsteins has been found to be 2% above that at 50° F., and the increase in Zebu, 60% above that at 50° F. This difference is due in part to size, since the reactions of the smaller Jerseys were between those of the Holsteins and Zebus.

The heat tolerance difference between European and Indian cattle, up to 95° F., is about 20°. The "comfort zone" (temperature interval during which no demands are made on the temperature-regulating mechanisms) of European cattle is between 30° and 60° F.; for Indian cattle between 50° and 80° F. Beginning at about 60° F. in European and about 80° F. in Indian cattle, the thermoregulative mechanisms became active, as shown by the abrupt and rapid increases in respiration and vaporization rates; beginning at about 80° F. in European and 95° F. in Indian cattle, these mechanisms began to fail, as shown by the abrupt rise in rectal temperature, decline in feed consumption, milk production, and body weight (Figure 2a). The above critical temperatures occurred indoors, with the same wall, ceiling, floor, and air temperatures, humidity at 50 to 60%, air movement 0.5 m.p.h., and constant day and night temperatures. The lower the night temperature, the higher the tolerated day temperature (Figure 1d, unpublished, by R. E. Stewart).

Many other changes not shown in Figure 2a occur on increasing temperature from 50° to 105° F., such as decline in thyroid activity, ascorbic acid and CO_2 combining power of the blood serum; and a rise in blood cholesterol, creatinine, and in respiratory alkalosis. This partly explains the deterioration of highly pro-

[1] Contribution of the Missouri Agricultural Experiment Station, Journal Series No. 1607. Approved by Director.

[2] The data were obtained cooperatively by the UM and USDA, with financial assistance of the AEC and ONR.

[3] Authored (with present writer as junior coauthor) by C. R. Blincoe (blood composition and radioisotopes), H. E. Dale (acid-base balance, blood volume, body water, rumen physiology), H. H. Kibler (respiratory exchange), A. C. Ragsdale and P. R. Cornelison (body weights and measurements), R. E. Stewart (reflective heating and cooling, surface and rumen temperatures), H. K. Thompson and R. G. Yeck (vaporization, water consumption, surface temperature), and Dorothy Worstell (data processing). The writer is particularly grateful to A. C. Ragsdale for encouragement and for permission to publish unpublished material.

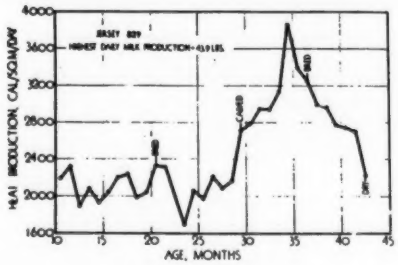

Fig. 1a

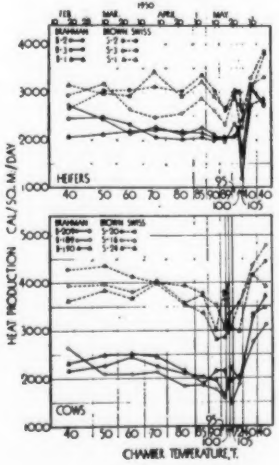

Fig. 1b

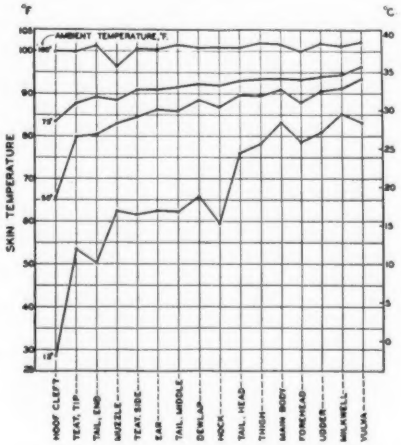

Fig. 1c

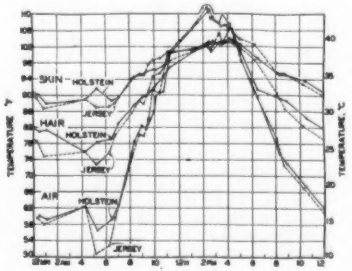

Fig. 1d

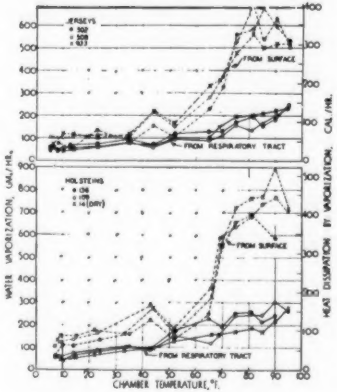

Fig. 1e

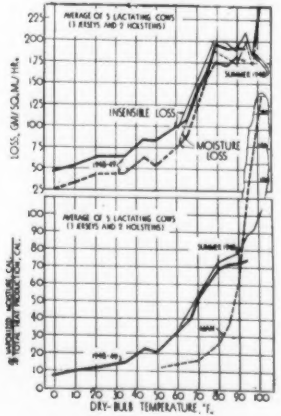

Fig. 1f

FIG. 1a. Heat production at the lactation peak is double that when dry.

FIG. 1b. Effect of temperature on the heat production of Swiss and Brahman heifers (upper segment) of nearly same weight and age, and of lactating cows (lower segment).

FIG. 1c. At air temperature 12° F. the cow's foot cleft temperature was near freezing of the tissues (30° F.) yet animals were entirely comfortable.

FIG. 1d. The skin temperature lags behind air temperature because of the damping effect of the large heat capacity of cows, from unpublished data by R. E. Stewart.

FIG. 1e. Relative vaporization from respiratory and outer surfaces.

FIG. 1f. Temperature effects on evaporative cooling.

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ductive cattle in tropical regions; or decline of milk yield and change in milk composition (rise in chlorides, decline in lactose, protein, nonfat solids) during exposure to high temperatures.

Productivity and Heat Tolerance

Indian-evolved cattle thrive in hot climates, but they are relatively poor milk (and meat) producers. European-evolved cattle are relatively high milk (and meat) producers, but they do not thrive in hot climates. Is it possible to combine high productivity with high heat tolerance?

Wide breed differences are determined by a series of genes of the multiple type, each gene having an additive effect. When the breeds are crossed, the genes recombine into new patterns. This way, by combining complementary genes, the backlogs of the evolutionary resources of both breeds may be utilized in producing new breeds, like Kleberg's King Ranch Santa Gertrudis cattle, which possess the high heat-tolerance characteristics of Indian and the high beef-production characteristics of European cattle. Although most crosses result in intermediate F_1 and F_2, a few F_2 may be superior to both parents, an effect known as transgressive variation, which seems to be exhibited in some ways in the Santa Gertrudis heifers studied in the Missouri Climatic Laboratory. Genetic combinations of desirable hereditary characteristics may also be obtained within a breed, but progress is much more limited; the more homozygous the breed, the more limited the progress. The studies in climatic physiology of different cattle breeds and strains may help in the development of high heat-tolerant yet high productive breeds, similar to the Santa Gertrudis cattle (Figure 3).

Shelter Needs of Cattle Against Cold and Heat

Protection against cold. The above citations, especially by Brown, on the great cold tolerance of European-evolved cattle, along with the results of the Heizer-Witzel barn experiments in Wisconsin published in 1952-53, and the Missouri Climatic Laboratory reports published in 1949-53 (Figure 1e) lead to the conclusion that European-evolved cattle are essentially arctic species. The expenditure of billions on warm barns therefore seemed unnecessary,

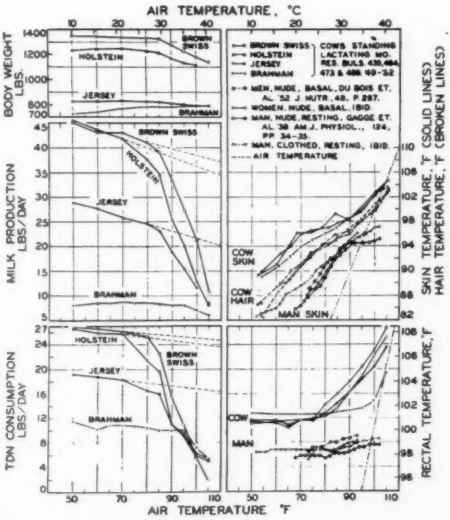

FIG. 2a. Temperature effects on several reactions of cattle and man.

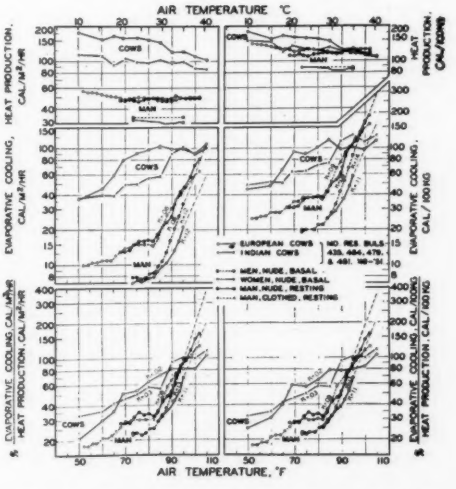

FIG. 2b. Temperature effects on heat production and evaporative cooling and on the ratio of evaporative cooling to heat production in cattle and man.

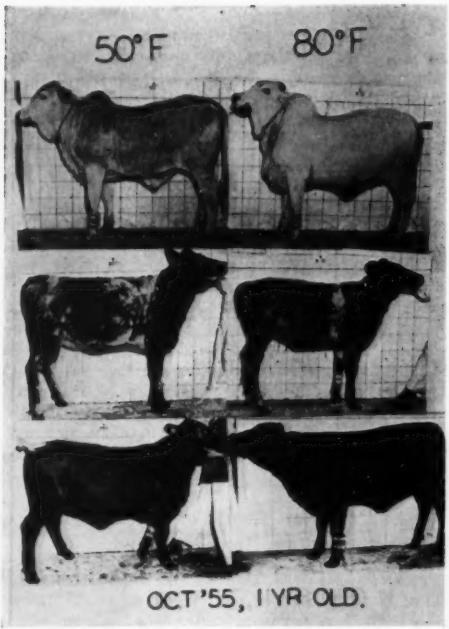

FIG. 3a. Photograph of Brahman (top), Shorthorn (middle), and Santa Gertrudis (bottom) heifers. Brahmans at 50° F. had darker hair than at 80° F. The Shorthorns at 80° F. were stunted, but the other breeds did equally well at 50° and 80° F.

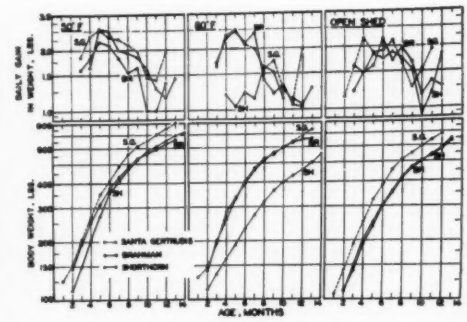

FIG. 3b. Age curves of growth in weight and in gain in weight at 50° F. (left), 80° F. (center), and open shed (right).

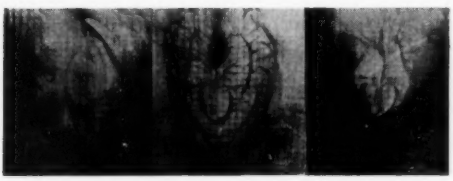

FIG. 3c. Relative heat-dissipating surface areas and vascularity of the vulvas of three categories of heifers at age 1 year.

being based on extrapolation to cattle of man's own sensitiveness to cold. Draft-free open sheds of proper length, width, and exposure, with low eaves on the open side for protection against snow and rain, and with the warm floor usually furnished by a slowly-fermenting manure pack in loose-housing systems seem sufficient even in the coldest states. Loose-housing systems eliminate the expensive and troublesome moisture- and ventilating-control problems and associated respiratory infection. However, a warm milking room must be provided for the cold-sensitive man who milks the cows.

Protection against heat. The deleterious effect of hot weather on cattle, on the other hand, calls for sheltering them against heat. The hot air layer that envelops the animal may be dissipated by conduction (especially in contact with cool water), convection (by breezes), and by vaporization.

Increasing air velocity from 0.5 to 5 m.p.h. reduced the heat stress of the cows between 75° and 95° F.; increasing it from 5 to 9 m.p.h. exerted much less cooling effect than increasing from 0.5 to 5 m.p.h.

Increasing radiation by lamps heated the animals to the same extent as hot air having as much heat as the lamp radiation energy. Sheltering must therefore include shade against sun radiation. Shades may range from trees and ancient-style straw-thatched roofs to ultra-modern (but no better) tall (12 ft.) metal shades painted with reflective white on the outerside and with absorptive black on the underside. Trees are best because their leaves are cooled by vaporization from their surfaces. Similarly, shade (portable) over pasture is cooler than over bare soil.

Increasing vaporization is the most effective method for increasing heat dissipation with rising temperature (Figures 4a and b). Kelly, Bond, and Ittner (1955) reduced by 19° F. the 100° F. air temperature under a shade roof by sprinkling a burlap subroof (and aluminum overroof). Such evaporative cooling is useful in dry regions (Imperial Valley of California) but not in humid regions (Nelson, Berousek *et al.*, 1956). Showers are also used to cool animals. Cattle learn quickly to use a shower actuated by a photocell.

The cooling effect of drinking cool water is slight by comparison to vaporization of the same amount, yet it is helpful. One Jersey (No. 212) greatly increased her water consumption with increasing temperature (Figure 4e) and so maintained her milk yield (Figure 4e). Standing in cool water is helpful in hot weather because of the great surface area per unit volume of leg.

TABLE 1

Evaporative cooling, heat production, and percentage of heat production that is dissipated by vaporization in European- and Indian-evolved cows[a, b] at different ambient temperatures in comparison to man[c]

Ambient temp.	Evaporative cooling/individual/24 hr.						Heat production/individual/24 hr.			Evaporative cooling, Cal. / Heat production, Cal.		
	European cows[f]	Indian cows[g]	Man	European cows	Indian cows	Man	European cows	Indian cows	Man	European cows	Indian cows	Man
(° F.)	(Cal. equivalent)[d]			(Moisture, Kg.)[e]			(Cal.)			(% ratio)		
50-55	4,560	3,470	432	7.8	6.0	0.7	19,860	11,920	2,376	23	29	18
60	5,880	3,600	456	10.1	6.2	0.8	18,660	12,080	2,232	32	30	20
70	9,700	4,180	600 (576)	16.7	7.2	1.0 (1.0)	19,300	11,770	2,016 (2,016)	50	36	29 (28)
80	12,120	4,850	624 (720)	20.8	8.3	1.1 (1.2)	18,350	10,640	2,088 (2,112)	66	46	30 (34)
90	11,780	8,120	1,296 (1,128)	20.3	14.0	2.2 (1.9)	14,940	10,430	1,968 (2,136)	79	78	66 (53)
100	12,260	9,440	2,520 (3,120)	21.1	16.2	4.3 (5.4)	13,580	9,800	2,112 (2,136)	90	96	119 (146)
102	12,500	10,000	2,712 (3,528)	21.5	17.2	4.7 (6.1)	13,100	9,750	2,112 (2,160)	95	102	128 (163)
105	13,200	10,740	4,104[h] (4,440)[h]	22.7	18.5	7.0[h] (7.6)[h]	12,640	9,620	2,112[h] (2,088)[h]	104	112	194[h] (213)[h]

[a] Data on cows, evaporative cooling, Bulls. 451, 461, and 497, "Environmental Physiology" Research Bulletin Series, Mo. Agr. Expt. Sta.

[b] Data on cows, heat production, Bulls. 435, 464, and 473.

[c] Data on man, male, resting, lightly clothed, Gagge, *et al.*, *Am. J. Physiol.*, **124**: 34. 1938. Values in parentheses are for man, male, resting, nude, *Id.*, p. 35.

[d] Latent heat of 1 kg. moisture = 0.58 cal.

[e] 1 kg. = 2.2 lb.

[f] Average of 6 Holsteins, 8 Jerseys, and 3 Brown Swiss, all lactating.

[g] Average of 2 lactating and 3 dry Brahmans.

[h] The 105° F. values for man were extrapolated from an arithlog plot.

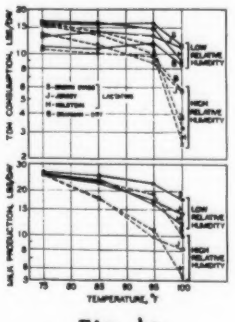

Fig. 4a

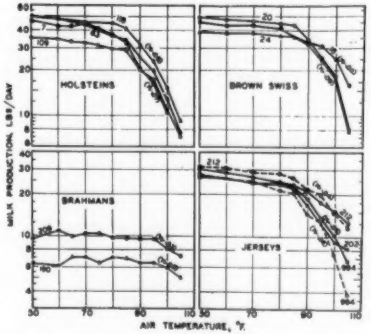

Fig. 4c

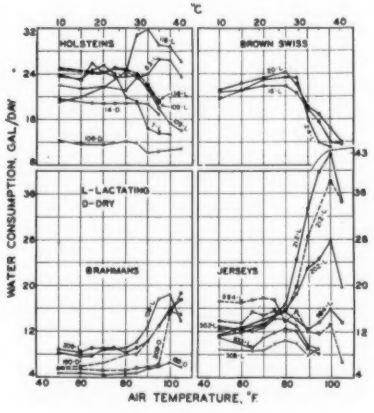

Fig. 4e

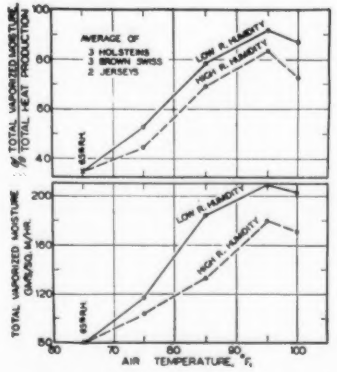

Fig. 4b

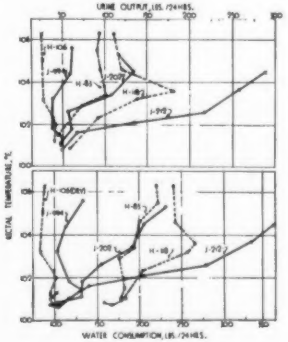

Fig. 4d

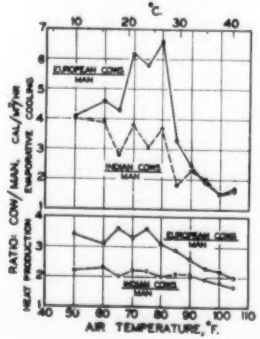

Fig. 4f

FIGS. 4a and 4b. Humidity effects at different temperatures. Cattle are extremely sensitive to humidity at temperatures above 95° F.

FIG. 4c. Temperature effects on milk yield. Jersey 212 increased most her cool water consumption and held up best her milk production.

FIG. 4d. The greater the water consumption (as in J-212), the higher the urinary output and the lower the rectal temperature.

FIG. 4e. Individual differences in the patterns of cool-water consumption with rising temperature. Those that drank most water held up their milk yield best.

FIG. 4f. Ratios of cow to man in evaporative heat dissipation and heat production. Cows vaporize 4 to 6 times as much moisture per unit surface area as man between 50° and 85° F., following which the vaporization rate dropped sharply due to the fact that the vaporization curve (Figures 1f and 2b) of cows is S-shaped in contrast to man's rise in vaporization.

Body-Temperature Regulating Mechanism

Breeds evolved in different climatic regions usually have adaptive characteristics which harmonize them with their respective climates. Some characteristics, such as hair thickness and size of peripherae (ears, dewlap, navel flap, etc.) are recognized on sight; others, such as neuroendocrine peculiarities are not visually apparent. The following is a summary of the rules governing climatic adaptations named after four pioneer investigators.

1. *Bergman Rule (1847)* relates body size to climate. The larger sized breeds are found in colder parts of the geographical range, the smaller in the warmer parts. This is illustrated by the pygmy races of elephant, hippopotamus, buffalo, and also pygmy man, in the hotter regions; and by the large breeds of cattle (Holsteins) in the colder USA states and small breeds (Jerseys) in the warmer states (Davidson, 1927). The Missouri Climatic Laboratory studies substantiate this conclusion: The small (Jersey) cows were more heat-tolerant and less cold-tolerant than the large (Holstein) cows (Figures 2a and 4c). These observations harmonize with the geometrical fact that small animals have larger surfaces per unit weight and therefore lose heat more rapidly per unit weight than large animals.

This reasoning applies to the extra-large skin folds which give a larger ratio of surface to weight and more rapid heat loss per unit weight. The ears, dewlap, navel flap, and vulva are much larger and more corrugated in the loosely built heat-tolerant and cold-sensitive Indian than in the compactly built cold-tolerant and heat-sensitive European cattle (Figure 3). The situation is somewhat similar to the greater heat tolerance of Merino sheep, which have large skin folds and therefore more surface per unit weight.

Some say that larger surface area per unit weight should not affect climatic tolerance because the "surface law" postulates that heat production—like heat dissipation—is proportional to surface area. This is true when it harmonizes with the principle of similitude, i.e., when the bodies are geometrically similar and the environmental temperatures are equivalent (under conditions of thermal neutrality). The extra skin area in Indian cattle seems to be an evolutionary adaptation to the extra difficulty in heat dissipation in the tropics; in the same way extra fur is an adaptation for extra heat conservation in the arctic.

2. *Wilson Rule (1854)* relates the insulating cover to climate. The warmer-coated breeds of a given species are located in the colder parts of the range, the less warmly coated in the warmer parts. This is illustrated by the downy, long, wooly, felting hair of European-evolved cattle, particularly Scottish Highland, with the short, smooth, glossy, straight, stiff hair of Indian cattle. Bonsma's European-evolved Shorthorn cattle hair weighed 300 g.; Africander's (Zebu), 10 g. Seasonal hair growth comes under this rule. The thick subcutaneous fat of the arctic species similarly contrasts with the lean skin of tropical species. There are no differences in skin thickness (independent of subcutaneous fat) between Indian and European cattle (Dowling, 1955).

3. *Gloger Rule (1833)* relates color to climate. Pigments in the bare skin protect against ultraviolet radiations. The hair, on the contrary, tends to be light-colored in the tropics to better reflect the solar radiations, thus keeping the animal from becoming overheated. Summer lightening and winter darkening of hair in cattle come under this rule although the greater survival value of protective coloration against predators may mask the tendency of protection against radiations. Increasing sebum secretion with increasing temperature, which gives the hair a reflective and protective sheen against solar radiations, also may be factors.

4. *Claude Bernard Rule (1876)* relates climate to changes in reactions not visually apparent. For instance, the temperature of the more exposed parts (ears, face, legs, feet) of arctic species is adjusted for heat conservation by vascular feedback or "servo" mechanisms, variously referred to as "heat economizers," "multichannel counter-current heat exchangers," "arterio-venous retes," *venae commitantes* or *venae comites*, whereby the heat from the warmer arterial blood going to the periphery is used to warm the returning cooler venous blood. In this manner heat loss from the warm arteries to the surface is reduced, the surface temperature is kept down, and the thermal gradient and the heat losses from the body are kept down.

A related method is the vasomotor dilating and contracting device that controls the rate of blood flow through the blood capillaries in the upper layers of the tissue so as to maintain proper surface temperature. This mechanism

TABLE 2

Evaporative cooling and heat production and percentage of heat production that is dissipated by vaporization at various ambient temperatures[a]

Ambient temp.	Evaporative cooling			Heat production			Evaporative cooling, Cal. / Heat production, Cal.		
	European cows	Indian cows	Man[b]	European cows	Indian cows	Man[b]	European cows	Indian cows	Man[b]
(° F.)	(Cal/m²/24 hr.)						(% ratio)		
50-55	990	789	240	4,320	2,709	1,356	23	29	18
60	1,280	818	264	4,060	2,745	1,272	32	30	20
70	2,110	950	336 (312)	4,200	2,675	1,152 (1,116)	50	36	29 (28)
80	2,640	1,102	360 (396)	3,990	2,418	1,188 (1,164)	66	46	30 (34)
90	2,560	1,845	732 (624)	3,250	2,370	1,116 (1,176)	79	78	66 (53)
100	2,670	2,145	1,428 (1,728)	2,950	2,227	1,200 (1,176)	90	96	119 (147)
102	2,720	2,270	1,536 (1,944)	2,850	2,220	1,200 (1,188)	95	102	128 (164)
105	2,870	2,441	2,328[c] (2,520)[c]	2,750	2,186	1,200[c] (1,188)[c]	104	112	194[c] (212)[c]

[a] Data on cows, same as Table 1, but using outer surface area as reference base. Data on lactating European cows are based on 3 Swiss, average weight 1,343 lb. (weight range 1,270-1,410 lb.); 6 Holsteins, average weight 1,221 lb. (weight range 1,125-1,270 lb.); 8 Jerseys, average weight 843 lb. (weight range 728-990 lb.). Data on Indian cows are based on 2 lactating (average weight, 730 lb., weight range 710-750 lb.) and 3 dry (average weight, 950 lb., weight range 930-980 lb.) Brahmans. The surface area was computed from the equation $A = 0.15W^{0.56}$ in which A is surface area in square meter, and W, weight in kg., for Jersey, Holstein, and Swiss cows. In computing the surface area for Brahman cows, an additional 12% was added for the extra area of dewlap, navel flap, ears, and hump. Surface area for European cows ranged from 4.5 to 4.7 M^2; for Indian cows, 4.3 to 4.5 M^2.

[b] Sources of data on man: same as Table 1.

[c] The 105° F. values for man were extrapolated from an arithlog plot.

TABLE 3

Average rectal, skin, and hair temperatures and respiration rates at various ambient temperatures[a]

Ambient temp.	Rectal temperature			Skin temperature			Hair temperature		Respiration	
	European cows	Indian cows	Man	European cows	Indian cows	Man	European cows	Indian cows	European cows	Indian cows
	(° F.)								*(Rate/minute)*	
50-55	100.7	100.9	98.2	88.2	89.0	82.6	83.0	82.6	25	16
60	100.7	101.0	98.4	90.7	90.8	84.0	86.6	86.7	28	16
70	100.8	100.8	98.4 (97.9)	94.8	93.9	87.6 (84.4)	90.3	90.5	39	19
80	101.5	101.4	98.4 (97.7)	96.5	96.0	91.2 (88.9)	94.1	94.3	69	24
90	103.4	101.5	99.0 (98.2)	98.5	98.4	94.6 (93.9)	96.5	96.7	98	48
100	106.0	103.5	99.3 (98.8)	102.0	102.6	97.0 (94.8)	100.2	100.9	107	82
102	106.6	104.4	99.3 (98.8)	102.8	103.0	97.2 (95.2)	101.4	101.6	108	89
105	107.6	105.6	—	104.0	103.7	—	103.3	102.7	110	110

[a] Sources of data: same as Table 1.

[b] Respiration rate for Indian cows: average of 2 dry and 2 lactating Brahmans.

is analogous in action to valves in thermostatic regulators that control steam supply to radiators. Claude Bernard discovered both of the above mechanisms in rabbits. He found that blood flow increased in their ears during very hot weather for cooling purposes, and again during very cold weather to warm the ears.

The Bazet group (1948) extended the above Claude Bernard studies to man and the Findlay group (1948-1955) to cattle. Cold-climate cattle (according to the Findlay group) are rich in vascular temperature regulators; warm climate species—exemplified by man—are poor in vascular thermo-regulators. By these methods the extremities of arctic animals tolerate very low temperatures. They are, moreover, able to function when their tissues and nerves are at 30° F. (Chatfield, Lyman, and Irving, 1953). This was also demonstrated in the Climatic Laboratory by the 30° F. temperature of the hoof cleft of cattle at ambient temperature 12° F. (Figure 1c). Tropically-evolved species cannot tolerate such cooling. It would, for example, be fatal for man to imitate the arctic gull that parades its slim bare legs at –40° F., or the Eskimo dog or arctic bear that walks on his naked foot pads at –60° F.

Differences in "racial metabolism," which may be due to dietary differences (Brobeck, 1948; Rodahl, 1952), and in more direct neuro-endocrine reactions, such as thyroid activity (Dempsey and Astwood, 1943), also come under this rule. Whatever the cause, the heat production per unit weight of Zebu heifers was found to be about 20% lower than that of the Brown Swiss heifers of about the same weight and age. Indian cows had much lower heat production (per unit surface area or per unit weight) than the Brown Swiss cows (Figure 1b). The lower "racial" heat production of Indian cattle may be another partial explanation for their higher heat tolerance (Figure 2a) and lower cold tolerance.

Increased respiration (panting) contributes to evaporative cooling in cattle (Figure 1e), but this cooling may be counteracted by the increased heat production from the "work" of panting. Panting also develops a respiratory alkalosis with decline in CO_2-combining power of the blood serum and a latent ketosis. The outer-surface evaporative-cooling method of body temperature control is more highly developed in tropically evolved species (man, donkey) than in arctic species (cattle). The low sweating rate (in comparison to man) in Indian cattle indicates that they have a remote arctic ancestry and a relatively recent tropical ancestry that enabled them to evolve the heat-dissipating peripherae and short reflective hair.

The problem of outer-surface evaporative cooling is confused by species differences in moisture-production methods and by semantic misunderstandings; hence the following definitions about the nature of the skin moisture are given.

Man produces skin moisture by: (1) eccrine sweat glands; (2) apocrine sweat glands which open into the hair follicles (in the axillae, pubic, and anogenital region); (3) passive cutaneous diffusion; and (4) sebaceous sweat glands (anatomically associated with the apocrine, both entering the hair follicles), which produce an oily material of slight water content. The thermo-regulatory vaporization in man above 80° F. is mostly eccrine sweat; below 80° F., mostly cutaneous-diffusion moisture. There is also, of course, vaporization from the respiratory tract (nose, mouth, pharynx, larynx, trachea, bronchi, lungs with their millions of moist air pockets). At about 95° F. man vaporizes about one-third of the total moisture from the respiratory tract, and two-thirds from the outer surface. The situation in cattle is shown in Figures 1e, 1f, and 2b.

Cattle have few, if any, eccrine glands. Skin moisture in cattle is apparently produced by cutaneous diffusion and by the apocrine sweat glands. The number of apocrine and sebaceous glands in cattle is determined by the number of hairs.

Cattle sweating was investigated most extensively by the Findlay-Yang group (1948-1955), which concluded that (unlike man's), cattle sweat glands are apocrine, have poor blood supply and low moisture production. Dowling and Ferguson (1955) reported that Zebu cattle "sweat" more than European cattle when exposed for a few hours to very high temperature and humidity. The long exposures to each of many temperature levels up to 105° F. at the Missouri Climatic Laboratory showed that Zebu cattle vaporize at a lower rate (per unit surface area or per unit weight) than European cattle, perhaps because Zebus produce less heat. The rate of vaporization at a given temperature is apparently determined by the rate of heat production in such a way as to maintain constant the ratio of evaporative heat dissipation to heat production at the given temperature. The writer believes that most vaporization from the skin of cattle is of cutaneous diffusion moisture. This belief is based on the absence of visible liquid on the skin in cattle kept in the Climatic Laboratory below 105° F., and on the failure of the Findlay group and the Missouri Climatic Laboratory to obtain (below 105° F.) sweat tests by the starch-iodine and quinizarin methods even after administration of sweat inducers. Methods of partitioning vaporized moisture between sweat and nonsweat (like methods for precise surface area measurements) have not been accomplished, which makes it an interesting subject for argument.

Comparison of Climatic Physiology of Man and Cattle

The close symbiotic association between man and cattle and the dairyman's tendency to confuse his own feelings of heat and cold with those of his cattle suggested the following comparison.

Man is climatically the most adaptable species because of his technology. In the nude,

however, without his technology, man is helpless in the face of temperatures below about 60° F. He is, however, very much more heat-tolerant than cattle. This is shown by his virtual normal and cow's 5° to 7° F. supernormal rectal temperature at 105° F. environmental temperature (Figure 2a).

Figures 1f and 2 and Tables 1 to 3 show the differences in several physiological reactions between man and cattle to increasing environmental temperatures ranging from 50° to 105° F.

The greater total vaporization per unit surface area in cattle between 50° and 85° F. (Figures 2b and 4f) is due partly to their relatively greater respiratory vaporization than in man. Thus at 70° F., a cow's respiratory vaporization was found to be 30 g/hr/m², and man's was 5 g/hr/m². However, the cattle and human sweating rate per unit surface area meet at about 90° F. (Figures 2b and 4f). The relatively dry cattle skin in contrast to man's moist skin in 85°-105° F. environment may be due to the higher skin temperature in cows, with corresponding higher vapor pressure of cattle skin and therefore more rapid drying of its available moisture. Thus in a 105° F. environment, the cow's skin temperature was found to be 105° F., man's, 95° F.; cow's rectal temperature, 107° F., man's, 99° F. (Figure 2a). The relative dryness of cattle skin may also be due to the greater vaporization surface furnished by their hair. The wetness of a cow's surface on bringing her in from the cool outdoors to the warm barn appears to be a condensation phenomenon, observed but rarely on animals held for days in the Climatic Laboratory at temperatures up to 105° F.

At temperatures below 100° F. the total vaporization per square meter was greater in cattle than in man, but the rise in the rate of vaporization with increasing temperature was very much steeper in man (Figure 2b). Whereas the cattle vaporization curve was S-shaped, becoming virtually flat at 85° F., man's sweating increased steadily from 85° to 105° F. at the rate of 9 to 13% per 1° F. rise in environmental temperature (Figure 2b and Table 2). The result of the difference in steepness of the vaporization curves was that at 105° F. the heat production that was dissipated by vaporization was about 105% in European cattle, 110% in Indian cattle, and 190% in man at 105° F. (i.e., 100% of the heat produced in man at 105° F. was dissipated by vaporization, and 90% more heat was dissipated in cooling the hot air passing through the respiratory tract and also dissipating the heat absorbed by the outer surface). In brief, the cow's intolerance to high temperature is reflected by her S-shaped evaporative cooling curve, which flattens out at 80° F. (Figure 2b) with resulting explosive rise in rectal temperature and decline in productive processes (Figure 2a) and related disturbances previously listed. Man's tolerance to the higher temperature is reflected by his breaking out in sweat at about 80° F. and his increasing in sweating rate at about 10% for each 1° F. rise in ambient temperature (Figure 2b). An additional heat stressing factor in cattle is the anaerobic rumen heat production, not included in the indirect calorimetry data (Figures 2b and 4f).

Summary

To show the progress made in acquiring knowledge of the relation of climate to the physiology of the dairy cow, the results of a comparative analysis of the reactions to different temperatures of three categories of cattle are presented. The studies dealt with cattle of the European, Indian, and Santa Gertrudis breeds housed in climatic chambers of constant day and night temperature with the same wall, ceiling, and air temperatures and the same humidity and air movement. Under these conditions, the "comfort zone" of European cattle was found to be between about 30° and 60° F. and that of Indian cattle 50° to 80° F. The higher heat tolerance of the Indian cattle seemed to be due to lower heat production, greater surface area per unit weight, shorter hair, and other body-temperature regulating mechanisms not visually apparent. The larger the animal and the higher her productive level, the lower was the "comfort zone" temperature. The inner body temperature was shown to be constant at about 20° F. above the comfort zone by an S-shaped increase in evaporative cooling. At 105° F. environment the near-lethal temperature of 108° F. was reached in the Holsteins, 106° F. in the Jerseys, and 105° F. in the Indian cows of the same weight as the Jerseys. At environmental temperature of 105° to 107° F. the European cows were near collapse. The Santa Gertrudis were found to be near Brahmans in heat tolerance; they grew equally well and maintained the same rectal temperature at 80° F. as at 50° F. The Santa Gertrudis were more cold-tolerant than the Indian heifers. Their critical temperatures have not yet been determined. The relative cold tolerance of Holstein and Zebu is indicated by a 2% increase in heat production in Holsteins and 60% increase in Zebu on lowering the temperature from 50° to 7° F. Acclimatized European cattle are cold tolerant and are not in need of protection against cold as such but only against wind, snow, and rain. They do need protection against heat. These findings show the practicability of loose-housing methods that have evolved in recent years and are now being commonly used by northern dairymen.

The Physiology of Milk Production

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The contributions to the field of physiology of milk production have been extensive in the past 50 years. Although results of this research may not have found such wide practical application as has been possible in other fields of the dairy industry, nevertheless, our fund of knowledge has been greatly increased. A number of fundamental contributions in the physiology of lactation have been made by investigators whose primary interest was the dairy cow. In order that others may not underestimate the importance of this field, perhaps one should remind them that without the udder there would be no dairy industry.

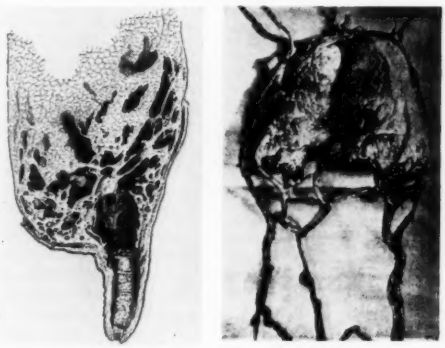
R. P. Reece

There can be little doubt that much of the early interest in mammary physiology stemmed from the desire to obtain a better insight into the secretory process of glands in general. Around 1905 there was disagreement as to whether the epithelial cells of the mammary gland contained one or two nuclei. Those who claimed the presence of a single nucleus contended that when two nuclei appeared it was the result of faulty histological technique. The gross structure of the gland, however, was fairly well pictured. It was known that the udder consisted of two halves and that each half had two quarters. The injection of different colored dyes into one half of an udder demonstrated the separateness of the two quarters. Prior evidence pointing in the same direction were the observations that: (1) Bloody milk may be drawn from one quarter while the other quarter of the same half yields normal milk; (2) cows may suffer from garget in one quarter only; and (3) all the milk from one-half of the udder cannot be removed by milking just one teat. Perhaps the best evidence of the separateness of quarters was the embryological finding in 1930 that each quarter originates from a separate mammary bud. In light of this convincing evidence it is interesting to note that not until the last edition of our best treatise on the anatomy of domestic animals is the statement made that the cow's udder consists of four quarters. Figure 1, depicting the gross appearance of a quarter of a cow's udder, was published in 1911.

In taking stock of the advances that have been made in the past 50 years it is impossible to develop them into a single picture. Therefore, separate attention will be given to the various fields of activity.

Anatomical Considerations

At the turn of the century it was common knowledge among investigators in the field that varying amounts of secretory tissue were to be found in the udders of cattle. It was known that the quantity of glandular tissue in the udders of beef cattle was small and that in good dairy cattle it was large—an observation of a physiological difference in beef and dairy types. Perhaps the most interesting comparison was the one made of Sophie 19th of Hood Farms and Blackbird of Dallas. It was reported in 1900 that the weight of dissected udders varied from 2 lb. 3 oz. to 41 lb. 6 oz., and continued attention has been paid to the weight and capacity of udders of dairy cattle. The empty weight of one udder was reported to be 165 lb., approximately 11% of the live weight of the cow, and highly significant correlations have been noted between producing ability and udder weight and capacity.



(1) (2)

FIG. 1. Longitudinal section of a quarter of an udder. From Van Norman, *First Lessons in Dairying*. Orange Judd Company, New York. 1911.

FIG. 2. Basal view of udder, showing the veins completely encircling the udder and leading away both forward and backward. From Bitting, *The Mammary Gland*. Indiana Agr. Expt. Sta., 12th Annual Report. 1900.

An early study showed that each half of the udder was enveloped in a strong fibrous capsule and that the fibers intermingled on the inner side and were prolonged upward as support for the gland. It was also noted that with advanc-

ing age the abdominal muscles may become more relaxed, resulting in a more pendulous udder. Over the years additional detailed studies of the structures supporting the udder have been made. The lateral and median suspensory ligaments have been shown to surround each half and give off deep lateral sheets which extend inward and downward to become continuous with the intraglandular interstitial framework. Claims were made in early reports of nerve endings on the epithelial cells of the mammary gland; however, more recent work has failed to demonstrate nerve fibers in contact with the alveolar epithelium. Several studies have been made which indicate that the nerves to the udder are of spinal and sympathetic origin, there being no evidence that parasympathetic nerves innervate the gland.

It is remarkable that a fairly complete description of the blood supply to, in and from the udder existed in 1900. It was reported that mammary veins from the glands on opposite sides anastomose both in front and behind so that there existed a complete circuit of veins around the udder (Figure 2). Although additional studies have been made on the circulatory system of the udder, the only significant change in the picture has been the description of the perineal veins and evidence indicating that the flow of blood in these veins is into the venous plexus rather than away from it.

One would expect to find significant additions to our knowledge of the histology of the cow's udder during the past 50 years, yet these additions have to do with details rather than with new structures. In 1900 the alveolus was described as a sacculated distention on the end of a minute milk duct. It was known to be lined by a single layer of epithelial cells, which were concerned with milk secretion. These epithelial cells were reported to vary from almost a flattened form to a columnar form during different stages of rest and activity.

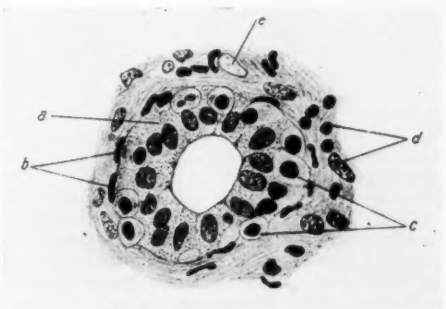


FIG. 3. Alveolus from the mammary gland of a goat at the time of parturition. *a*, epithelium; *b*, basketcell; *c*, white blood corpuscle; *d*, connective tissue nucleus; *e*, blood capillary. From Grimmer, *Chemie und Physiologie der Milch*. Verlag Paul Parey, Berlin. 1910.

Figure 3 is reproduced from a 1910 publication. The existence of basket cells around alveoli and ducts was noted in 1904, and these cells have been beautifully demonstrated in recent studies by staining with silver. The abundance and orientation of this myoepithelial tissue strongly indicates that it functions as a contractile tissue which expresses milk from the alveoli and ducts.

Mammary Gland Growth

Since the amount of secretory tissue in the mammary gland is often a limiting factor in milk production, one would expect to find considerable attention devoted to normal mammary gland growth. It has been shown that the secretory tissue of the udder arises from the ectoderm and that udder shape and form are established during intra-uterine development. The duct system is limited to sprouts just emerging from the gland-cistern region, and there is some evidence that this region may not be completely differentiated at the time of birth.

Histological studies on mammary glands of heifer calves are not extensive; however, the studies that have been made indicate that udder development, from birth to puberty, keeps pace with body growth. Any increase in the size of the udder is largely the result of fat deposition, well-conditioned calves showing greater udder size than nonthrifty calves. The results of a recent investigation suggest that excessive fleshing during the growing period may interfere with subsequent lactational performance. A study of the development of the udder of heifer calves from 1 to 18 months of age, as determined by digital palpation, has been carried on for a 21-year period (1927-48). At 5 months of age for Holsteins and 4 months of age for Jerseys the correlation between palpation grade and subsequent milk and butterfat production were all highly significant. In a separate study it was reported that estimated sizes may be very different from the true sizes although the two were generally highly correlated. In most instances the estimated sizes were significantly smaller than the true sizes.

A histological study on the udders of virgin heifers was recorded in 1907. Considerable variation in the development of glandular tissue was noted; alveoli were absent and duct epithelium exhibited no signs of secretory activity. In 1927 it was observed that ovulation and corpus luteum formation were followed by a marked development of the duct system in the udders of heifers. During recurring estrous cycles duct growth is additive, up to a certain point, and the extent of duct development at the time of conception is dependent upon the number of estrous cycles experienced.

Based on visual observation of changes in udder size it was believed that most of udder growth occurred shortly before parturition. Studies of the udders of heifers pregnant for

the first time, however, have indicated some duct extension followed by lobule-alveolar proliferation during the first half of pregnancy; this was followed by the gradual initiation of secretory activity during the second half of pregnancy. These findings in heifers were confirmed and extended in a large group of laboratory animals. It has been assumed that similar changes occurred in animals pregnant and lactating. Recent work on the mammary gland of the rat, however, indicates that mammary hyperplasia continues into the second half of pregnancy and that mammary development in pregnant lactating animals does not duplicate the picture found in pregnant nonlactating animals. In lactating and pregnant animals mitotic activity was found to be nil except just prior to parturition. Under such circumstances a rather large number of epithelial cells developed during the first gestation would continue to function in the second lactation period.

It was shown in 1922 that mitosis rarely occurs in the lactating gland. Since then it has been reported that cell division occurs shortly after parturition, after which it becomes rare, and soon it cannot be demonstrated at all. Observations made in 1907 suggested that a gradual inactivation of the alveolar epithelium occurred during the declining phase of the lactation period. Later the studies in rats, mice, and goats have shown that the stimulus arising from suckling or milking aids in maintaining the alveolar epithelium and finally that injected lactogenic hormone can substitute for the stimulus of milking. In a number of animals it has been shown that in the absence of pregnancy there is a rather rapid loss of the lobule-alveolar system after the cessation of milking.

A little over 50 years ago physiologists were of the opinion that the growth of the mammary gland during pregnancy was dependent upon nerve connections between the uterus and mammary glands. Experiments on the transplantation of mammary glands followed and they demonstrated conclusively that mammary growth could occur in the absence of normal nervous connections. These findings served as the foundation for later brilliant work on the hormonal control of mammary growth.

Around 1900 a group of papers was published which showed that ovariectomy of sexually immature animals prevented the usual changes that occur in mammary glands after puberty. Normal growth, however, was noted when the ovaries were grafted successfully into another site. These investigations helped to establish the ovary as a gland of internal secretion.

Estrogens, at first available only after laborious extraction procedures, were then shown to be the main stimulators of mammary duct growth. In some species (mice) estrogens stimulated duct growth only, whereas in other species (guinea pigs) they induced complete mammary gland growth. Still other species fell between these two extremes, the amount of lobule-alveolar growth depending upon dose and duration of treatment. Results from experiments on the initiation of lactation suggest that estrogens alone in intact dairy cattle induce varying amounts of lobule-alveolar growth.

In 1911 it was observed that lobule-alveolar growth occurred whenever functional corpora lutea were present, and it was thought that the corpus luteum was the source of a hormone stimulating this growth. Aqueous extracts of lutein tissue, however, failed to induce lobule-alevolar growth of the mammary glands in animals in which the corpora lutea had been removed. There then followed reports from two laboratories indicating that an extract of corpora lutea (progestin), which produced progestational proliferation of the uterus, did not induce proliferation of the mammary glands. At about the same time it was noted that large amounts of estrogen were excreted during pregnancy, and it was believed that the lack of effect of progestin on the mammary glands might be due to the absence of estrogen. Upon the simultaneous injection of estrogen and progestin into castrated rabbits mammary development similar to that occurring during the first half of pregnancy was observed. After progesterone became available from pharmaceutical houses, it was shown that progesterone alone in larger doses (unphysiological doses) would stimulate lobule-alveolar development in ovariectomized animals. For efficient progesterone utilization, however, estrogen must be present. Finally, a considerable amount of work has been conducted which shows that for maximum lobule-alveolar growth and the development of a normal alveolar epithelium there must be a proper estrogen-progesterone ratio. Moreover, this ratio is not constant but changes from one species to another.

In the early 1930's it was believed that the endocrine control of the mammary gland had been worked out fairly well. In a review paper, however, an eminent pioneer in endocrine research ignored all of the work that had been carried out on the endocrine control of the mammary gland. When his attention was called to this omission, he indicated his knowledge of the beautiful studies in the field but pointed out that such experiments had been carried out on animals in which the pituitary glands were intact. There then followed considerable experimentation in an attempt to elucidate the role of the anterior pituitary in mammary growth. Perhaps never before has an omission stimulated such intensive research!

The first work with hypophysectomized animals, which came from laboratories in Europe (1932), indicated that estrogens were effective in stimulating mammary duct growth. A large number of papers then appeared, the majority

of which reported lack of mammary growth in animals completely hypophysectomized. Attempts were then made to determine the route of action of steroid hormones in bringing about mammary proliferation. Initial studies suggested that estrogens stimulated the anterior pituitary to secrete the factor(s), later termed mammogen, that induced mammary gland growth. The inunction of estrogen on one row of mammary glands in rabbits with pituitaries intact resulted in growth of the glands on that side only, thus indicating a direct action of estrogen on mammary glands. Some workers interpreted the results of inunction experiments as indicating that a pituitary factor was not essential for mammary growth. That such was not the case, however, was shown when estrogen aplied locally to mammary glands failed to stimulate growth in hypophysectomized animals. It was then shown that estrogens plus the lactogenic hormone would induce mammary duct growth in hypophysectomized animals. If the lactogenic hormone is the pituitary factor that is essential for mammary duct growth, then estrogens act directly and indirectly in stimulating mammary growth since it has been shown that estrogens stimulate the pituitary gland to secrete the lactogenic hormone. There exist rather good reasons for believing that the pituitary factor facilitates and permits the action of estrogen on the mammary gland.

Attention was then directed toward ascertaining the role of the pituitary gland in lobule-alveolar growth. It was shown that estrogen in conjunction with progesterone did not stimulate lobule-alveolar growth in pituitaryless animals. The inclusion of the lactogenic hormone, however, induced lobule-alveolar growth although it was not equal to that which takes place during pregnancy. It was then demonstrated that lobule-alveolar growth comparable to that occurring during pregnancy could be obtained by injecting the growth hormone, the lactogenic hormone, estrogen, and progesterone.

In 1935 papers began to appear indicating a placental role in mammary gland changes during the second half of pregnancy. Among the pituitary, ovaries, fetuses, and placentae the placenta was the only one which by itself would prevent mammary involution. Evidence for a direct mammary-growth stimulating principle in placentae was reported in 1955.

Initiation of Lactation

It has been known for many years that lactation is held in abeyance during pregnancy. In 1931 it was reported that mammary secretory activity during the early stages of pregnancy, in heifers pregnant for the first time, remained at about the same level as that observed prior to conception. During the second half of gestation there was an increase in secretory activity with a striking increase about 20 days before parturition. After parturition there is a great surge of secretory activity, and a number of attempts have been made to account for the secretory activity of the mammary gland during pregnancy and at the time of parturition. At the time when our association was founded it was believed that lactation set in after the removal of an inhibitor that was thought to be of placental origin. Somewhat later it was shown that the removal of the corpus luteum in late pregnancy in the goat initiated lactation, an observation that suggested the corpus luteum as the source of the substance which suppressed lactation during pregnancy. Interesting indeed is the fact that in 1926 it was postulated that an unknown inhibiting hormone was responsible for the decreased milk production after the fifth month of gestation in lactating and pregnant cows. It was then noted that estrogens had the ability to decrease established lactation and, since estrogen excretion rates increased during pregnancy, the idea developed that estrogen might be the inhibiting agent during pregnancy. This information, along with additional experimental results, was utilized in 1936 to formulate a theory whose main tenets were that estrogen inhibited the secretion of the lactogenic hormone and in addition had a direct inhibitory action on the mammary gland. Extensive lactogen assays subsequently established the fact that estrogen does not inhibit lactogen secretion but actually stimulates its production, thus tending to discredit the theory proposed in 1936. A new concept was advanced in 1942 in which it was suggested that progesterone inhibits the stimulatory effect of estrogen on lactogen secretion during pregnancy. At parturition the overriding influence of progesterone was thought to be removed, thus leaving estrogen free to stimulate lactogen secretion. This concept can now be questioned since it has been shown in two species that progesterone blood level does not decrease at parturition.

Endocrine Control of Lactation

The first evidence of a pituitary-mammary gland interrelationship appeared in 1910, when it was shown that a single intravenous injection of an extract of the posterior lobe of the pituitary gland into a lactating goat with a cannulated teat resulted in a rapid increase in milk flow through the cannula. The effect was transitory, and a second injection resulted in a decreased effect. These results were confirmed in other animals, but it now seems certain that these posterior lobe extracts are not true galactagogues but stimulate milk let-down. Over a considerable period of the existence of our association one will find that many substances were tested to determine their effect on milk production. It was not until 1928, however, that evidence was presented for the lactation-initiating properties of an extract of the anterior lobe of the pituitary gland. This obser-

vation stimulated considerable research on the endocrine control of lactation.

Investigators in several laboratories have confirmed the ability of an extract of the anterior lobe of the pituitary gland to initiate lactation in rabbits ovariectomized at the end of pseudopregnancy. These observations were quickly extended to other animals and there followed extensive work on the extraction, isolation, and characterization of the active principle in the anterior pituitary. Although the active principle, the lactogenic hormone, could initiate lactation in animals with suitably prepared mammary glands, it did not augment established lactation. Experimental results then established the importance of other endocrine factors in lactation.

In 1933 results began to appear showing that the removal of the pituitary gland during pregnancy resulted in lactation failure after parturition. Similar results were obtained in other species, and it was also noted that hypophysectomy during lactation caused a rapid and complete cessation of milk secretion. Somewhat surprising was the fact that the lactogenic hormone did not serve as replacement therapy for the pituitary gland, since it was then the only known anterior pituitary lactation-factor. Results were forthcoming, however, which placed the pieces of the puzzle together.

Adrenalectomy resulted in failure of animals to lactate normally and, moreover, it required considerably more adrenal cortical extract to support lactation than it did to maintain life. Then followed experimentation, the results of which demonstrated the ability of the adrenal cortical extract plus the lactogenic hormone to maintain lactation in hypophysectomized animals. Since the anterior pituitary contains a principle, the adrenocorticotropic hormone, that stimulates adrenal cortical function, it was logical that the next step was the work which demonstrated that the lactogenic hormone plus ACTH would maintain lactation in hypophysectomized animals.

Although the adrenal glands are usually considered essential for lactation, nevertheless, evidence has been presented which indicates that lactation failure is not complete after adrenalectomy. On the basis of work reported this year, hydrocortisone would appear, in regard to lactation, to offer replacement therapy for the adrenal glands.

The influence of the thyroid gland on lactation has attracted considerable attention during the past 50 years. In 1907 in the goat, and in 1934 in the cow, it was reported that thyroidectomy resulted in decreased milk flow. Of even greater interest was the finding in 1934 that thyroid feeding during the declining phase of lactation resulted in an increase in milk production and an even greater increase in fat production. In the same year it was shown that thyroxine injections produced similar results, and these observations were confirmed and extended subsequently in a number of laboratories. These thyroxine studies added greatly to our knowledge of factors influencing milk and milk-fat secretion; however, no practical application of the results was possible because of the excessive cost of thyroxine. This hindrance, however, was soon alleviated by the formation in vitro of highly active thyroproteins. Thyroprotein has been fed to dairy cattle for extended periods of time, and considerable information is available on the advantages and disadvantages of thyroprotein feeding.

Studies have been made on the relation of the parathyroids to lactation although they are not extensive and the results are not in agreement. A study reported in 1945 indicates that lactation following parathyroidectomy is severely impaired but not completely abolished. Some attention has been given to the influence of the endocrine pancreas on milk production. It was shown in 1931 that the injection of large doses of insulin decreased milk production in the cow. Studies conducted on the dog indicate that, in regard to initiation and maintenance of lactation, insulin offers replacement therapy for the endocrine pancreas.

Various steroid hormones, either alone or in combination, have been used to prepare animals for lactation. Some animals have produced very well, but the outstanding characteristic of responses has been the tremendous variation.

Milk Secretion Process

The question of the time when milk is secreted has attracted the consideration of workers over the period under discussion. Around 1900 it was generally held that milk formation increased enormously during the milking act. This view was held as late as 1924 even though experimental evidence began to appear in 1915 indicating that most of the milk was present in the mammary gland at nursing or milking time.

One of the main reasons for believing that milk secretion was rapid during the milking act was the belief that the udder could not possibly hold all the milk obtained at one milking. The results of udder volume determinations were such as to indicate that the milk obtained at milking time was much greater than udder capacity. The amount of milk obtained at postmortem milking was only about half of the expected production. Moreover, it was shown in 1926 that intramammary pressure increased markedly and suddenly during the milking act, and this was believed to be due to the rapid secretion of milk at that time.

The picture began to reverse itself in 1915 when it was reported that the volume of a salt solution that could be injected into a goat udder after milking was greater than the volume of milk removed. Similar results were obtained by other investigators and this led to the

conclusion that the mammary gland could hold all of the milk obtained at one time. The lactose content of mammary glands was then determined, and this method of estimating the amount of milk in the glands gave amounts greater than would have been expected since variable quantities of milk remain in the udder after milking. Various improvements were then made in carrying out postmortem milkings and this resulted in obtaining greater quantities of milk than had been secured in earlier experiments. In addition, the quantity of liquid that could be injected into an amputated udder was greater than the amount of milk obtained at previous milkings. If large quantities of milk were formed during the milking act, there would have to be a tremendous increase in the flow of blood to the udder, and evidence for this does not exist. Finally, the increase in intramammary pressure at milking time has been shown not to be due to the rapid secretion of milk. If milk is not removed, the pressure will fall to what it would have been if the animal had not been stimulated.

If milk is not secreted during the milking act, then it must be secreted during the milking pause, and there is indirect as well as cytological evidence indicating that such is the case. Udder pressure has been shown to be zero after complete milking; it increases gradually for a time and then increases more rapidly as the milk-collecting spaces fill.

Around 1900 it was suggested that during milk secretion the nuclei of epithelial cells wore out and were replaced by mitotic or amitotic division. Subsequent work, however, has shown that the cells of the alveolar epithelium tend to retain their integrity during the lactation period. Some evidence has accumulated indicating that the Golgi apparatus takes an active part in the secretory activity of the epithelial cells of the mammary gland; it hypertrophies during lactation and fragments during involution of the mammary gland. More recently there has been a tendency to attribute the synthetic properties of cells to the mitochondria with the Golgi apparatus serving to concentrate synthesized material into droplets.

There has been considerable speculation regarding the role of the nervous system in milk synthesis. At one time it was believed that a nerve center controlling milk secretion, although not identified, was located in the spinal cord. Secretory nerve fibers directly controlling milk synthesis have not been demonstrated, and evidence of the independence of milk synthesis from the nervous system is indicated by experiments with transplanted mammary glands and by udder perfusion experiments. Sympatheetomy has not interfered with lactation, and in 1941 it was shown that sectioning the sympathetic fibers to one half of a cow's udder did not influence milk secretion. Sensory nerve fibers from the mammary gland, however, are essential for the maintenance of lactation since impulses conveyed by these fibers stimulate the anterior pituitary gland to discharge the lactogenic hormone.

In 1906 it was stated in a textbook that milk was formed from the blood, partly by the transudation of the blood serum directly into the lumen of the alveolus and partly by the transformation of the contents of the epithelial cells. Water passed directly from the capillaries into the alveoli and ducts, carrying along the mineral constituents in solution and a part of the albumin of the blood serum. It was thought that the larger part of the albumin was in some way changed during its passage from the capillaries, appearing in the lumen of the alveolus as milk casein. The cell contents were thought to be changed into fat globules, the globules being either extruded through the cell wall into the lumen or set free by the breaking down of the cell wall. It was further indicated that fat could be carried over directly from the blood to appear in the milk without change. Milk sugar was thought to be formed through a chemical change in the contents of the epithelial cells since only minute quantities of sugar were found in the blood.

In order to gain further insight into the mechanism of milk synthesis, numerous studies have been conducted in an attempt to determine the blood precursors of milk constituents. Final answers, undoubtedly, have not been obtained, but steady progress has been made with the development of new techniques.

The results of a study on jugular and mammary venous blood differences were published in 1906, jugular blood being used in lieu of arterial blood. The jugular-mammary venous technique has been employed in several laboratories and was used as late as 1938. In 1932 it was shown that jugular blood composition may differ considerably from that of arterial blood and as a consequence may give misleading results. At the same time, results of arteriovenous studies on the udder were reported, the arterial blood being obtained from the radial artery. In subsequent work various techniques were developed for obtaining arterial blood, blood samples being obtained from the artery leading to the udder by puncture through the rectal or vaginal wall, by cardiac puncture, and by exteriorizing the carotid artery. It has been repeatedly emphasized that the arterial and venous blood samples must be taken as nearly simultaneously as possible and that they must be obtained with a minimum of disturbance to the animal if one wishes to avoid misleading results. In order to avoid disturbances to the animal, nembutal anesthesia has been used. In goats it has neither altered milk secretion rates nor affected blood sugar utilization. The results of such A-V studies indicate whether or not a given blood constituent is being taken up by the mammary gland, but they do not indi-

cate whether a sufficient amount is being taken up to account for the observed rate of synthesis of the corresponding milk constituent. In order to make such determinations, the ratio of blood flow to milk secreted must be known; such ratios have been reported to be from 150-650 : 1.

Various organs of the body have been removed and perfused with blood in physiological studies; the technique was first used on the mammary gland of the ewe in 1912. Two groups of workers have since developed the technique for perfusing the bovine mammary gland. The perfusion technique has been shown to have distinct advantages as well as definite limitations. An entirely different method for the study of mammary gland metabolism was reported in 1935. Mammary slices were incubated with various possible precursors of milk constituents in well oxygenated salt solutions. Finally, the use of radioactive isotopes appeared to offer a valuable procedure for the study of milk precursors; the results of such use were reported in 1938.

Three milk constituents, milk fat, casein, and lactose, are not present in the circulating blood, and lactose and casein are produced nowhere in nature but in the epithelial cells of the mammary gland. It is logical, therefore, that the precursors of these three milk constituents have received the greatest amount of consideration.

The results of a number of investigations indicate that glucose is concerned in lactose synthesis and is probably its main precursor. It was reported in 1906 that mammary venous blood from lactating cows contained less glucose than jugular blood, whereas in a dry cow the glucose contents of the two kinds of blood were nearly equal. In 1912 it was reported that in using the perfusion technique results were obtained which indicated that lactose was formed from glucose but not from galactose. The results of A-V studies have shown consistently an uptake of glucose by the udder of lactating cows, the amount varying from 5 to 15 mg. %. One report in 1942 indicated A-V glucose differences of sufficient magnitude to account for the lactose synthesized provided that none of the glucose was used for energy production or conversion to fat. In addition, the results of studies conducted with mammary tissue slices have indicated that glucose is one of the main precursors of lactose. Studies involving the experimental alteration of blood glucose level have indicated a relationship between blood glucose and lactose; a lowering of milk lactose content has been shown to accompany hypoglycemia induced by inanition, insulin, or phlorizin, and rather small increases of milk lactose content have been noted in certain instances of induced hyperglycemia. An additional source of carbohydrate for the mammary gland was indicated in 1941 when a definite uptake of glycoprotein was observed. The results of other experiments have suggested that glycogen may serve as an intermediary in lactose synthesis or as a store of carbohydrate.

An uptake of amino nitrogen by the udder of the lactating cow but not of the dry cow was reported in 1920 when the jugular-mammary vein technique was used. These results led to the belief that milk proteins were synthesized from amino acids of the blood. Subsequent arterio-venous studies confirmed these findings; however, quantitative arterio-venous work showed that the amino acid uptake from the blood was insufficient to account for the milk proteins. It was then shown that globulin was taken up by the mammary gland, and it was suggested that globulin might be transformed into milk protein by the gland. The uptake of glycoprotein, believed to be globulin, by the lactating goat udder was reported in 1941. Various tests have shown that lactalbumin and serum albumin are two distinct proteins, and it appears that lactalbumin may be synthesized from the same precursors as casein. The epithelial cells of the mammary gland appear to be permeable to globulin since serological tests have shown that blood globulin and milk globulin are identical. The precursor of the phosphorus of casein has been shown to be the inorganic phosphate of blood.

Early attempts were made to feed fat into milk, and it has been shown that the fats, carbohydrates, and proteins of feed can be utilized for the production of milk fat. Data recorded in 1919 from studies in which the jugular-mammary venous technique was employed showed that phospholipids were higher in jugular blood of lactating cows than in mammary venous blood. These findings led to the theory that milk fat originated from phospholipids of blood. Subsequent work with the anterior-venous technique, however, failed to show any uptake of phospholipids by the udder of the lactating cow. That neutral fats might be the precursors of milk fat was indicated in 1912 when a sheep's udder was perfused with an emulsion of olive oil. An aqueous fluid containing fat globules was secreted, the iodine number of which was lower than that of the fat in the perfusion fluid. Perfusion experiments, the results of which were reported in 1929, showed that the udder could absorb neutral fats, and several A-V studies have given results indicating that neutral fats are the main, if not the sole, precursors of milk fat. There was a sufficient uptake of neutral fats in one A-V study to account for the fat in the milk. The results of several experiments have shown that the respiratory quotient of the lactating udder is greater than unity, and this has been taken to indicate that a portion of milk fat is synthesized from carbohydrate. Short-chain fatty acids characterize the milk fat of ruminants, and there has been considerable conjecture regarding their origin. Results from several labo-

ratories have been interpreted as indicating that they may be formed in the udder from long-chain fatty acids by a process of oxidation followed by reduction. On the other hand, recent work indicates that acetate is utilized in the synthesis of the short-chain fatty acids of milk fat.

Milk Discharge

From the cells. Various theories, based upon cytological studies, have been advanced as to the mode of discharge of milk from the cells. Evidence was available around 1905 which indicated that the epithelial cells lining the alveoli were not discharged with their secretion. Such a mode of discharge would require rapid cell proliferation, and no one had demonstrated this in the lactating gland. There is now abundant evidence indicating scarcity of division of epithelial cells during the lactation period. The secretion then could be discharged either from a cell that remained intact or discharged after the rupture of the cell wall, the latter mode being termed cell decapitation. In 1907 a paper presented the view that the secretion was normally extruded from intact cells and that evidence of loss of cellular cytoplasm during discharge was an artifact of histological fixation. Subsequent studies have not been in agreement on mode of discharge, some indicating that cell decapitation does occur, others indicating that it does not, and still others favoring a combination of cell decapitation and extrusion through the intact cell wall. A rather recent consideration of the problems favors the cell decapitation theory.

From the udder. In a textbook printed in 1906 it was claimed that the branching points of all milk ducts, large and small, were guarded by sphincter muscles. It was believed that these muscles were connected with the abdominal muscles and that the cow was able to close them more or less completely at will and so "hold up" her milk. Animals were thought to vary greatly both in the control they possessed over the muscles and in their disposition to use it.

It has taken more than 50 years to evolve the story on milk let-down. In 1876 it was shown that the increased discharge of milk, caused by the stimulation of the inguinal nerve, did not occur when the external pudic artery was pinched off—thus indicating that the substance causing milk let-down was carried to the udder in the blood. Nevertheless, a view widely held was that the stimulus of milking caused sensory impulses to be conveyed to the central nervous system, which in turn sent motor impulses to the smooth muscle of the udder via the inguinal nerve. This smooth muscle contraction was thought to be responsible for milk let-down. Another theory that received some support was that the stimulus of milking caused the udder to become engorged with blood, the result of which was to force the milk from the lumina of alveoli and the finer milk ducts. Although later work proved this theory to be untenable, nevertheless, a 1955 edition of a textbook on the physiology of domestic animals still holds to the view that the erection of the teats and ease of milking is controlled by a blood sinus at the base of the teat which becomes engorged at milking time.

In 1910 it was shown that the intravenous injection of an extract of the posterior lobe of the pituitary gland resulted in an increased flow of milk from a cannulated teat of a goat udder. Then in 1915 a paper was published in which the similarity between the action induced by posterior lobe extracts and the normal let-down reflex was noted. That the nervous system was involved in the let-down of milk was shown by the inhibition of this phenomenon in an anesthesized bitch. Later the effectiveness of posterior lobe extracts was demonstrated in cattle.

The ability of posterior lobe extracts to elicit milk let-down having been demonstrated rather conclusively, attention was then directed toward determining the importance of motor impulses to the udder. Sectioning of the inguinal nerve did not interfere with normal milk let-down, and let-down was obtained in an excised gland when it was perfused with blood obtained from a cow after let-down had been induced.

Pituitrin was separated into two principles in 1928, oxytocic and pressor, and both caused milk let-down, the former being more effective than the latter. Until recently, however, each principle was contaminated with the other one and there existed some doubt regarding the identity of the let-down hormone(s). This doubt has now been removed by brilliantly conducted chemical work in which the chemical make-up of the oxytocic principle has been determined. This was followed by the preparation of a synthetic material that possessed oxytocic activity. Similar progress has been made with the pressor principle since synthesis of the proposed octapeptide structure has led to biologically active material, material with pressor, antidiuretic, and milk let-down activity. Hence it would appear that the milking act stimulates the discharge of the hormones of the posterior pituitary, which in turn bring about the contraction of the myoepithelial tissue in the udder.

Not all of the milk present in an udder is removed at milking time. This has been shown by experiments in which udders were analyzed for their lactose content and by the intravenous injection of pituitrin after normal milking. The mean amount of milk available after the intravenous injection of 10 units of oxytocin was 5.7 lb. in one study and 1.7 lb. in another. These observations have indicated the importance of a good milking routine in order to obtain as much milk as possible at each milking. One of the most profound changes in milk

removal from the udder has been the increase of the use of milking machines. In 1941 there were 210,000 milking machines on farms, whereas in 1950 there were 710,000.

Conclusion

What are the results of the studies on the physiology of milk production? First, there is a much better understanding of the entire milk secretion process, which offers considerable satisfaction to those with inquiring minds. Second, physiological differences between high and low producing cows are becoming apparent and it may be possible eventually to use this information in the breeding of dairy cattle. Third, with further experimentation it should be possible to prepare consistently barren dairy animals for lactation.

The American Dairy Science Association can be proud of the contributions made by its members to the physiology of milk production.

Nutrition and Feeding of Dairy Cattle

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In 1906 the average cow in the United States produced approximately 2,500 lb. of milk; in 1956 she produced more than 5,000 lb. This improvement reflects in a general way the impact of developments in the science of selecting and husbanding dairy cattle during this semicentennial period. Although the extent of its contribution cannot be precisely reckoned, the science of nutrition and feeding has had a significant influence. The fact that most studies have shown that the heritability of milk yield is less than 0.3 whereas 50 to 70% of the variation in yield is caused by environmental factors indicates the great importance of feeding.

J. T. Reid

The basic feedstuffs employed in 1956 are essentially the same ones fed to cattle in 1906. But the proportions in rations, the total amounts fed, and the extent of supplementation employed are different. In some cases, the contents of certain chemical constituents in feeds have changed because of alterations in the methods of preservation and preparation, in the genetic constitution of plants, and in the conditions under which plants are grown. Corresponding changes in feeding practice have been prompted by developments in nutritional science either alone or in combination with economics.

Underlying the development of information on the nutrition and feeding of dairy cattle has been the marked metamorphosis in attitudes towards, and concepts of, nutrition as a science. Before 1900 the bovine was sometimes employed as the experimental subject, though not necessarily because this species was economically important. As recent as the turn of the twentieth century, animal husbandmen charged with the care of dairy cattle at public institutions were reluctant to allow biochemists and physiologists the use of the animals in scientific studies. Accounts have been recorded of S. M. Babcock's attempts to study the nutritive qualities of rations composed of single plants. After much frustration, he was allowed the use of two cows, one of which died a few months after the experiment began, thereby ending the project. Several years later, however, Babcock's younger associates (Hart, Humphrey, McCollum, Steenbock) were able to conduct such an experiment and, as a result of using such simple diets, were led to the discovery of the first vitamin. The value of the immediate animals used in a given experiment was oftentime prejudged to be greater than the potential benefits of the results. Though even today the practicality of some experiments is condemned by some husbandmen, the development of husbandry as a "hybrid" science has done much to obviate this attitude during the last 50 years. Accompanying this evolution and as the body of knowledge has expanded in interrelated fields, specialists in husbandry, chemistry, physiology, pathology, bacteriology, medicine, economics, engineering, and statistics have formed teams to provide greater competency in the solution of many phases of a given nutritional problem.

Before and during the era of Babcock and his contemporaries, most of the contributions to nutritional science were made by researchers who were trained basically in pure chemistry or physics or in the medical sciences. Since that time there has gradually evolved in America the present-day worker in dairy cattle nutrition whose training as an undergraduate is in agriculture (generally animal husbandry) and as a graduate is in biochemistry and/or physiology with supporting training in one or more of the fields of mathematics, physics, pathology, bacteriology, botany, genetics, zoology, or economics. Used hardly at all before 1906 and still not accepted by all workers, statistics has become an important tool in determining the design of nutritional investigations as well as in providing means of detecting treatment differences and of delineating and describing degrees of differences.

Status of Nutritional Knowledge in 1906

The body of knowledge relating to the nutrition of dairy cattle that had accumulated by 1906 is perhaps greater than present-day investigators like to admit, particularly if they are engaged in problems recognized in 1906 that are yet unsolved. In 1906 protein, lipids, carbohydrates, and mineral matter were the only nutrient groups recognized; none of the vitamins had been discovered. The work of Armsby, Kellner, Hagemann, and Lawes and Gilbert had demonstrated that body fat may originate in dietary fat, carbohydrates, or protein. Jordan and Jenter in 1897 had shown that the cow can form milk fat from nonfat dietary substances. The chemical nature of the recognized nutrient groups was better understood than the biochemical, physiological, and pathological effects of deficiencies or excesses upon the animal.

Chemical knowledge. In 1786 Berthollet found that nitrogen is a constant component of ani-

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mal tissues, and in 1789 de Fourcroy noted similarities between plant and animal proteins. As a result of finding that acid would hydrolyze proteins, Braceonnot in 1822 discovered the amino acids, glycine and leucine. Mulder, who coined the term "protein" in 1838, believed that proteins consisted of a nucleus of definite proportions of carbon, hydrogen, nitrogen, and oxygen but that their differences depended upon their contents of sulfur and phosphorus. It was his belief that protein is the most important of all organic substances. This probably led Boussingault in 1844 to evaluate rations for livestock on the basis of their nitrogen content.

The presence in plants of sodium (de Monceau, 1736), phosphorus and potassium (Marggraf, 1743 and 1761, respectively), and of calcium, sulfur, and silicon (Hassenfratz, 1789) had been reported. Iodine was discovered in burnt seaweed by Courtois in 1811, and fluorine was found in teeth by Gay-Lussac and Berthollet in 1805 and in the bones of a calf by Bibra in 1844. Lehmann in 1895 found copper in animal tissues. By 1830, Liebig had perfected methods for the quantitative measurement of carbon, hydrogen, and oxygen. Chevrieul discovered in 1814 that the hydrolysis of fats yields fatty acids and glycerol, and in 1832 he isolated creatine from muscle tissue. In 1789, de Fourcroy isolated cholesterol from bile. A variety of organic acids (tartaric, citric, oxalic, malic, lactic, and uric) were prepared singly by Scheele between 1742 and 1786 and, in 1798, Vanguelin discovered benzoic acid.

Marggraf discovered sucrose in 1743 and lactose in 1747. The fermentability of various sugars was determined and the acid hydrolysis of starch had been effected by the early 1800's. Vogel found in 1815 that glucose reduces alkaline compounds of metals and von Beyer in 1870 proposed the aldehyde nature of glucose for which the empirical formula had been already established (1830 to 1840). It was not until 1875, however, that Bernard found that glucose is the sugar in blood and that the liver can store glucose as glycogen and reconvert it to glucose. This brief account illustrates the relatively high state of development of chemistry even long before 1900, as it became related to nutrition.

Disturbances associated with unknown dietary causes. Although by 1906 the performance of animals and, in some cases, harmful or curative effects, were associated with the consumption of certain feeds, not many disturbances were associated with a lack or excess of a specific nutrient. White muscles in cattle were reported by Faucon in 1897. Such abnormalities as faulty bone and teeth formation were attributed to inadequate dietary calcium and phosphorus; the perverted appetites and physical disability observed in 1884 by Hutcheon in cattle grazing in South Africa were found in 1903 to respond to phosphorus supplementation. Excessive weight losses were believed to be the result of an inadequate intake of total feed or protein. But, the causes of conditions such as faulty skeletal structures in cattle consuming considerable calcium and phosphorus, sore eyes, blindness, abortion, hair and hoof losses, heart lesions, exostosis, anemias, hemorrhage, muscle degeneration, and tetany, which have since been attributed to specific dietary defects, were unknown in 1906. By that time numerous reports were made of a syndrome characterized by blindness, staggering gait and, eventually, death in cattle consuming cottonseed meal. Although the cause of the condition was believed to be toxic substances in cottonseed meal, it gradually developed by 1928 that the rations containing cottonseed meal were in fact deficient in vitamin A, though cottonseed may contain substances toxic to other animals. According to Niborg (1795) bloat was not a serious problem until about 1750 when the grazing of clovers became a common practice. The basic cause of bloat was not known in 1906. At that time, though, prussic acid in sorghums, kafirs and Johnson grass, ergot in rye, saltpeter in commercial fertilizers, and unknown substances in spoiled sweet clover were known to be toxic to cattle. In 1862, Voelker blamed the ill effects of teart pastures on an abnormally high content of nonprotein nitrogen.

Experimental techniques used. A number of experimental techniques, which proved to be useful during the period 1906 to 1956, were introduced prior to 1906. In 1784 Spallanzani employed perforated tubes to study the rate of passage of ingesta through the gastro-intestinal tract. He concluded that ingested feed spends 25 hours inside the cow. By means of ruminal fistulae, Toussaint (1875), Flourens (1884), and Colin (1886) were able to contribute the early knowledge of digestion in ruminants and to establish some of the differences between ruminants and monogastric animals with respect to this function.

Boussingault conducted the first balance trial with a cow in 1839. This technique has served as one of the major means of feed evaluation ever since. In 1846 Liebig emphasized his belief that only the nutrients that are transformed into blood are of value to the animal. In an attempt to measure the degree of absorption of several dietary components at various levels of the tract as well as the total absorption, Wildt in 1874 employed silica occurring naturally in the diet as a reference substance. This was the first attempt to employ what has become known as the digestibility-indicator method.

In 1842 Liebig fractionated feedstuffs into protein, lipids, and carbohydrates. The system of proximate analysis of feedstuffs (known as the Weende method), in which provisions are made for the chemical separation of water, ether extractives, crude protein, ash, and crude fiber and the computation of nitrogen-free ex-

tract by difference, was introduced by Henneberg and Stohmann in 1860. Despite the recognition by these workers of certain defects in the method, it is employed today essentially in its original form. That the proximate analysis, even in conjunction with digestibility data, does not provide a consistently accurate description of the nutritive value of feedstuffs was well recognized by others prior to 1906, however.

Studies dealing with energy metabolism had their beginning in 1770. Between 1770 and 1794, when he died by the guillotine, Lavoisier demonstrated that in respiration the oxygen of inspired air combines with carbon and hydrogen and that the amount of food consumed and work performed influence the amount of oxygen consumed and carbon dioxide voided. About a half-century later (1849) Regnault and Reiset devised the first closed-circuit respiration apparatus, which they used in studies of gaseous exchange by several kinds of animals, among which were calves. They found that small animals used more oxygen per unit of body weight than did large animals and attributed the difference to the relatively greater body surface area per unit of body weight of the small animals. This seems to have been the beginning of knowledge relating body surface area to metabolic rate, though this was theorized by Sarrus and Rameaux in 1839. In addition to the contributions made to the physiology of heat production by the body and factors influencing respiratory quotients and gaseous losses, the observations made were being related to the diet consumed and, particularly, to the mutual replacement values of the nutrients. Of much aid in these experiments, particularly with farm animals, was the open-circuit respiration apparatus designed by Pettenkofer and Voit in 1862. These studies were conducted successively by Henneberg and Stohmann, Kuhn, Zuntz, Rubner, Atwater, and Kuhn's successor, Kellner, and others during the period 1860 to 1906. Henneberg and Stohmann recognized that the digestible nutrient value of feeds is a limited index of nutritive value and, between 1865 and 1870, attempted to evaluate feedstuffs in terms of protein and fat deposition as derived from carbon and nitrogen balances. This technique became increasingly important and was the basis of the method employed by Kellner to determine his starch-equivalent values reported in 1905.

The slaughter-chemical analysis method introduced by von Bezold in 1857 was employed two years later by Lawes and Gilbert in studies of three cattle and by Soxhlet in 1876 to determine the amount of protein and other substances stored by calves fed milk. Probably because of its costliness as well as the relative cheapness of determining the amount of protein and fat deposited by means of carbon-nitrogen balances, the slaughter technique was not employed again in experiments involving the whole bodies of cattle until about 1920, though Waters in 1908 employed it in the study of carcasses.

Protein and energy needs. It is difficult to state a definite time in history when notice was taken of the nutritional importance of protein. Between 1850 and 1900, protein received considerable attention, however, as Liebig, Pettenkofer and Voit and Pflüger proposed theories concerning the mechanism by which it is metabolized by animals. Stohmann in 1869 probably is the first worker to point out that the apparent digestibility of protein increases as the protein content of feeds increases. In 1905 Folin suggested that protein catabolism consists of an endogenous form which is characterized by a fairly constant excretion of nitrogen represented largely by creatinine (in addition to neutral sulfur) and of an exogenous form which is characterized by a variable urinary loss represented chiefly by urea. Although cattle were not employed in these early studies, similar studies were conducted with cattle prior to 1906. As a consequence, it was well established that the constant breakdown of tissues results in a loss of nitrogen in the urine at all times and that the degree of loss depends to some extent upon the amount of nitrogen consumed. In starvation, the excretion of nitrogen was found to reach a minimum level, which remained constant until the animal perished. It was recognized that when the dietary supply of protein is in excess of the amount needed to maintain nitrogen equilibrium, the excess protein, although not stored as body protein, is not wasted, since it may be converted into glycogen or fat. In 1900 Kellner showed that carbohydrates and fat tend to spare the wastage of body protein from cattle fed low-protein rations. As a result of the slaughter-analysis studies and the findings that digested protein is stored to the extent of 75 to 90% in young calves consuming milk and of 10 to 15% in mature nonpregnant cows, preliminary views on the quantitative needs for protein had been formulated by 1906. In 1860 Henneberg and Stohmann found that 0.57 lb. of digestible protein is required for maintenance by mature cattle weighing 1,000 lb., and Wolff in 1864 recommended 0.7 lb. for the same purpose. A summary of Kuhn's data by Kellner in 1894 indicated that the requirement for maintenance is 0.7 lb. of digestible crude protein per 1,000 lb. of body weight. The higher allowance (0.6 lb. of digestible crude protein per 1,000 lb. of body weight per day) for maintenance proposed in 1903 by Armsby is still recommended in feeding standards in 1956. Although all feeding standards proposed before 1906, beginning with that of Wolff (1864), contained provisions for the rationing of protein, only that of Haecker (1903) was based upon actual feeding trials with milking cows. The high economic value of protein turned attention to studies (conducted after 1906) aimed at determining the minimum amounts of protein needed to sup-

port maintenance, growth, and lactation. In 1879, Weiske *et al.* fed asparagine as a source of nitrogen. In 1891, Zuntz suggested that ruminal microorganisms use the nitrogen of amides, amino acids, and ammonium salts in preference to that of protein, and Hagemann in 1891 suggested that the protein stored in the bodies of microorganisms is digested in the lower gut of the host; however, despite limited additional study, this was still in question in 1906.

Although the maintenance and production needs of cattle were not considered separately until 1887 when Kuhn suggested it, the energy or digestible nutrient needs for maintenance had been recorded earlier. In 1860 Henneberg and Stohmann found that cattle weighing 1,000 lb. required daily 7.97 lb. of digestible matter, whereas Wolff in 1864 recommended an allowance of 9.1 lb. Kuhn in 1894 reported a requirement of 7.3 lb. of digestible matter per day per 1,000 lb. of body weight. Haecker in 1903 proposed 7.9 lb. of TDN per day per 1,000 lb. of body weight as the maintenance need of cows, and this value is widely accepted in 1956. The maintenance needs for net energy were found by Kuhn (1882-1890) and Kellner (1900) to be approximately 6 therms per 1,000 lb. of body weight, but variable depending upon the fatness of the animal.

Mineral needs. The mineral needs of cattle had been given attention as early as 1859. In that year Lehmann reported on his mineral balance trials with calves. He concluded that a ration of barley, rapeseed, limited milk, and hay provided enough magnesium but insufficient calcium. He observed that about half of the calcium phosphate added as a supplement was utilized, and he pointed out that hays are the chief common feed source of calcium. Weiske drew similar conclusions in 1873, and Soxhlet in 1878 found by slaughter-analysis that a 2-week-old calf stored 97% and 73% of the calcium and phosphorus, respectively, provided by an all-milk ration. In 1880, Voit described the abnormal bone growth observed in rickets resulting from the consumption of low-calcium rations and he pointed out that calves do not suffer from this disturbance as much as do pigs. In 1898 Anger, a German, reported that when milk production exceeded 24 lb. on a particular ration, cows were in negative balances of calcium and phosphorus. Abnormal conditions in cattle characterized by lack of appetite, depraved appetite leading to the eating of bones, reproductive disturbance, and broken bones were recognized in Germany during the period of 1860-1875 by von Gohren, Bauer, Nessler, and Grouven. Stohmann and Nessler believed that the cause was the low contents of phosphorus and/or calcium in the hay. In 1894 Kellner held the same view. From 1880 to 1906 much study was given to the mineral needs. Such studies as those of Neumann (1893) and those conducted at Moekern (1902) and the Wisconsin Experiment Station showed that cattle can assimilate the calcium and/or phosphorus contained in calcium phosphate and carbonate, bone ash, steamed bone, and ground rock phosphate, and that certain rations require supplementation to ensure adequate bone formation. By 1906 it was recognized that forages, particularly legumes, are good sources of calcium and that some concentrate feedstuffs are of a relatively high phosphorus content. Although Howell had stated that the mineral salts are used in the metabolism of the body, the mechanisms of their functions and the quantities needed for various functions had not been worked out by 1906.

The essentiality of salt (sodium chloride) in the diet of cattle was known long before 1906. The early belief that salt has a favorable effect upon the digestibility of rations and other similar ideas had been disproved. It was well established, however, that salt may serve as a condiment and, when consumed in excessive quantities, is harmful. Of all experiments conducted to that time, only that of Babcock and Carlyle in 1905 provided conclusive information. All cows deprived of salt for 2 to 3 weeks showed an abnormal craving for it, but milk production, live weight, and general appearance of the cows did not decline until after a month, and in many cases, after one year. Finally a sudden breakdown of the cows occurred, from which they would recover when salt was provided. Potassium chloride effected the recovery of one cow. Their recommended allowances of 0.75 to 1 oz. of sodium chloride per 1,000 lb. of body weight per day and 0.03 oz. per pound of milk produced have been accepted to this day.

The importance of iodine in nutrition was recognized in 1820 when Coindet found a goiter-curative principle in burnt sponge and was emphasized in 1833 when Boussingault stated that this element is the only known specific agent effective in treating goiter and suggested that it be added to salt. It was not until 1895, however, that Baumann discovered that the iodine content distinguishes the thyroid gland from other organs.

In 1896 Aston described an anomaly characterized by emaciation, loss of appetite, and anemia in cattle grazing in New Zealand. Iron licks provided in the form of limonite effected a complete cure in some cases but was ineffective in others. It was not until 40 years later that a deficiency of cobalt was found to be the primary cause of the condition.

Digestion physiology and chemistry. In 1826 Tiedmann and Gmelin observed that milk drunk by calves passes directly to the abomasum, though, according to Peyer in 1685, Faber appears to have been the first to describe the essential function of the esophageal groove. Attempts to rear calves on limited amounts of milk were described in the early literature. Boussingault in 1845 described milk substitutes

consisting of hay tea and suspensions of oil meals, and Liebig at about the same time prepared gruels from various concentrate feeds. All-concentrate rations fed to calves for as long as 8 months were found to be unsatisfactory by Sanborn in 1893 and Davenport in 1897. Calves on such diets ceased to ruminate and were unthrifty, presumably because of a lack of roughage and consequent multiple deficiencies. Although Ehrlich in 1892 had demonstrated with mice the importance of colostrum in immunization, the factors responsible for the beneficial effects of cow's colostrum upon calves had not been determined by 1906.

During the latter part of the nineteenth century many advances in the knowledge of the digestive processes were made as outlined in the books by Colin and Pavlov. Much interest was shown in the cow's production of large amounts of saliva and in the differential development of the stomach compartments from birth to maturity. Much of the nature and functions of the major digestive enzymes elaborated by the true stomach, intestines, and pancreas and the action of bile were understood before 1906. This is to say that the digestion of protein, fats, and simple carbohydrates as it occurred in the true stomach and intestines was known. However, the digestion of complex carbohydrates and the function of the first two stomach compartments of the cow were not so completely worked out in 1906, though theories did exist.

Although fiber digestion by cattle was observed by Sprengel in 1832, and Haubner and Sussdorf in 1855 stated that it is not effected by secretions of the gastro-intestinal tract, it was not studied chemically until 1860 by Henneberg and Stohmann. The latter group found that fiber utilization was improved by increasing the proportion of protein to other organic constituents of the ration and pointed out that the indigestible fraction of fiber is lignin. Others, particularly Konig in 1871 and Stutzer in 1875, also believed that lignin is indigestible.

Tiedmann and Gmelin (1826) found that the cow's rumen produces carbon dioxide, ammonia, and butyric acid. In 1870 Grouven suggested that the digestion of cellulose, a major constituent of fiber, yields certain fatty acids and gases. Between 1875 and 1885, Zuntz, Tappeiner, and others demonstrated that some of the end products of fiber digestion are carbon dioxide, methane, and hydrogen and acetic, butyric, propionic, and other fatty acids. Tappeiner in 1881 suggested that the digestion of cellulose in the cow's rumen is effected by microorganisms. The attack on cellulosic materials by microorganisms was not demonstrated by direct microscopic methods, however, until 1918. Although Zuntz did not offer evidence in support of his belief, he suggested that the butyric and acetic acid so produced served as a source of energy for cattle. In 1885 Henneberg and Stohmann, noting discrepancies between their chemical data and the knowledge that cellulose is a valuable nutrient, postulated that ruminants absorb intermediate products of rumen fermentation.

Eventually it evolved, as demonstrated by Headdon in 1897, that the crude fiber of roughages consists largely of cellulosic substances and smaller quantities of lignin. Zuntz had pointed out in 1879 that the digestion of fiber, different from that of starch, requires a considerable expenditure of energy. During the last four decades of the nineteenth century, cellulose was held in disrepute apparently because of its bedfellow, lignin. Kellner (1905), demonstrating that the digestibility of cellulose liberated from lignin by alkali is high and that the energy value of digestible cellulose is equivalent to that of digestible starch, did much to improve the nutritional standing of cellulose.

Feed utilization and values. Between 1870 and 1906 numerous advances in the knowledge of feed utilization were made. The digestibility of the proximate constituents of many feeds was determined and many of the limitations of digestion trials were worked out. It had been pointed out by Armsby in 1884 and others that much of crude fiber is converted to methane which, though combustible, has no nutritive value. In digestion studies, the measurement of fat as ether extract includes many substances which are not true fat, and feedstuffs vary in their contribution to nonfatty ether extractives. Large quantities of highly digestible carbohydrates such as sugars and starch were known to reduce the digestibility of crude fiber and protein in the rations to which they were added (Henneberg and Stohmann). Studies had been made of the comparative digestive efficiency of sheep and cattle. In one of these studies reported in 1906 by Kellner, cattle were able to digest 11% more of the dry matter in straws than were sheep, though the difference for concentrates was nil. Kellner ascribed the differences observed to the relatively low water content in the large intestine of sheep. In experiments conducted between 1895 and 1900, Jordan demonstrated that the digestibility of the dry matter may be as much as 5 percentage units higher for mixed rations fed at maintenance levels than for the same rations fed at full-feed levels.

By 1906 considerable information existed on the nutritive value of various feeds and on factors affecting it. Studies of the influence of growth stage of forages at the time of harvesting upon their nutritive qualities had been reported by Deetz (1873), Kellner (1879), Jordan (1882), Richards (1883), Wilson (1884), Morse (1888), Mills (1896), Widtsoe (1897), Peter (1900), and others. As a consequence, it was known that generally as the stage of growth approaches maturity, the concentrations of nitrogen, ash, lipids, and nitrogen-free extract decrease and that of crude fiber increases. In addition the palatability and diges-

tibility of forages were found to decline as growth progressed. It was well recognized prior to 1906 that the effects of growth stage are common to many different species of plant. Mainly because of their higher contents of protein, their productivity and role in maintaining soil fertility, legumes were regarded more highly than nonlegumes. Although beginning in 1898 Henry had based his emphasis of the high nutritive value of legumes upon their protein content, it was not until 1910 that he emphasized the value of the mineral matter as well as that of the protein in legumes. This reflects the great amount of attention given to this subject during the very early 1900's.

In 1899 Ladd, working at the Geneva Experiment Station, reported his classic studies on the development of nutrients in an acre of corn. The dry matter yield increased steadily from the tassel to the ripe stage, the gain being most striking between the silking and glazing stages. Over two tons of dry matter were stored in less than 1 month after August 9 (silking stage). Mineral matter, protein, and crude fiber increased up to about the glazing stage but not to the ripe stage, whereas nitrogen-free extract continued to increase to the ripe stage. Most of the increase between tasseling and ripening was due to the accumulation of starch in the grain. The detailed information obtained in Ladd's study provided a basis for the management of corn crops to be used as different forms of feed.

Although information at that time was meager, Lawes and Gilbert in 1900 had demonstrated that the chemical composition of crops could be influenced by the chemical composition of the soil on which they are grown.

Forage preservation. In 1884, Armsby showed that cows consuming artificially dried or sun-dried grass produced the same amount of milk as those fed fresh green forage cut from the same source. Leaf loss and changes in chemical composition during the process of preserving harvested forages were considered to have an important effect upon nutritive quality. Rainfall was found by Wolff in 1895 and Headdon in 1896 to reduce the dry matter and protein and to increase the fiber content of harvested forage markedly.

Early attempts to avoid nutrient losses employing various means of preservation have been recorded. Beet leaves and other green forages appear to have been preserved in "pit" silos covered with earth in Europe as early as 1850. In 1877, Goffart, a French farmer, published his "Manual of the Culture of Siloing of Maize and Other Green Crops," which was based upon 25 years of practical experience. He outlined the peculiarly suitable characteristics of corn as an ensilable crop. In 1876, Francis Morris built the first vertical silo in America in Howard County, Maryland. In 1881, I. P. Roberts at Cornell University and W. A. Henry at the University of Wisconsin constructed and filled the first silos employed experimentally in America. The use of hydrochloric acid as perhaps the first exogenous silage preservative was introduced by Giglioli in 1885.

The Vermont Experiment Station chemically analyzed a sample of grass silage provided by a farmer in 1887 and, between 1891 and 1897, carried out extensive studies on the chemical composition and feeding value of grass silage. Despite the considerable research conducted up to 1900, much difficulty was experienced at that time with top and side spoilage (Cooke) and with the ensiling of legumes (Shaw). The relatively greater success had in ensiling nonlegumes as compared with legumes was attributed to the higher sugar content of nonlegumes. Even as recently as 1910, Henry stated that "alfalfa is primarily a soilage and hay plant and, while it can be made into silage, it is less satisfactory for that purpose than Indian corn, and should only be ensiled when it cannot be cured into hay."

Comparisons made of the nutrient losses from corn and grass silages generally favored the corn silage. Between 1890 and 1900 comparisons made of corn silage and fodder at the Pennsylvania, New Jersey, Vermont, and Wisconsin Experiment Stations showed that the loss of nutrients from, and the digestibility of, the two kinds of corn forage are about the same but that cows consuming the silage had higher intakes of dry matter and produced more milk.

Rationing and feeding standards. It was recognized early that not all feedstuffs have the same nutritive value and that relative replacement values are needed in rationing. The earliest attempt to work out equivalents for various feeds appears to be that of Thaer in 1809. Thaer considered that the total substances found to be soluble in water, alcohol, acid, and alkali by his associate, Einhof (circa 1800), represented the feeding value. He then expressed these values for various feedstuffs in terms of a standard hay, which unfortunately is one of the most variable of feeds fed to cattle. The use of Thaer's hay-equivalent method ceased by about 1860 as digestibility data began to accumulate. However, another system of feed equivalents and corresponding allowances for weight gain and milk production was proposed by Fjord in 1872 based upon a feed reference unit of 0.5 kg. of equal parts oats and barley.

The first feeding standard, as they are known today, was proposed by Grouven in 1858. He set forth ration allowances of crude nutrients as defined by Liebig in 1842. As the experiments of Henneberg and Stohmann (1860) began to demonstrate weaknesses of earlier methods of assessing feeding value, Wolff in 1864 began to publish annually the allowances of individual digestible nutrients in Mentzel and von Lengerke's Agricultural Calendar. His

values were modified from time to time and were supported by data obtained in feeding trials. During the early days, the ration was considered as a whole in making allowances for animals. In 1887, Kuhn suggested that the ration should be considered in two portions; one for maintenance and the other for milk production. Beginning in 1897 Lehmann revised Wolff's tables to put them in accord with the suggestions of Kuhn and continued to publish them until 1906. Rationing for milking cows was refined further in 1903 by Haecker, who demonstrated that the amount of nutrients needed to produce milk depends not only upon the size of the animal and quantity of milk produced but also upon the fat content of the milk. Kellner in 1905 published his feeding standards expressed in terms of starch equivalents and digestible true protein. This standard did not provide a separate allowance for maintenance and production nor an allowance for the production of milk of various fat contents.

The foregoing sketch is by no means a complete history to 1906 of the nutrition of dairy cattle. Rather, it is intended to represent the development of a broad range of facts in order to establish the status of knowledge on this subject as it existed in 1906.

Development of Nutritional Knowledge Since 1906

Between 1906 and 1956 the efforts of many workers resulted in determining the essentiality of several nutrients not recognized previously, in relating to the total dietary regimen nutrients already known, in determining some of the means by which energy is liberated and used, and in relating these and other segments of knowledge to feeding practice and dairy cattle husbandry in the formulation of rations. Naturally, in many cases the progress made since 1906 on a given problem was influenced by the attention given to it prior to 1906.

MINERAL ELEMENTS

Calcium and Phosphorus

Prior to 1906 the essentiality of calcium and phosphorus in the diet was recognized, but the symptoms as observed in the naturally occurring deficiencies of these elements were in some cases confounded with those of other nutrient deficiencies. The minimum requirements for growth and lactation had not been determined and vitamin D had not been discovered. The early studies of Soxhlet in 1878 and of Lawes and Gilbert in 1883 provided a basis for Kellner in 1907 to estimate that the calf during the first year of life needs to retain an average of 15 and 8.3 g. per day of calcium and phosphorus, respectively. Armsby in 1917 proposed almost identical figures.

Disturbances associated with geographic area. The importance of mineral elements in the nutrition of dairy cattle, though recognized to some extent since 1860, was revived especially during the 1920's when a variety of disturbances in various parts of the world were found to have a similar nature. The conditions observed included anorexia, depraved appetite, abnormalities in bone formation and maintenance, stiffness, lameness, reproductive failures and, in some cases, anemia and diarrhea. Aston and Reakes, working independently, concluded from their studies in New Zealand between 1905 and 1910 that a deficiency of both phosphorus and iron was the cause of the condition known as "bush sickness." This was based in a large part upon their observations that the forage was low in phosphorus and that some animals responded to treatment with limonite. In Australia, Henry in 1912 was convinced that the major dietary defect causing the osteomalacia which he observed in cattle was phosphorus and he fed bone meal as a preventive. Between 1920 and 1933, these and other disturbances were described: "lamziekte" and "stifziekte," Theiler *et al.* in South Africa; osteomalacia, Tuff in Norway; "lechsucht," Konig and Karst in Germany; bone chewing, Welch in Montana; "loin disease," Schmidt in Texas; pica, and reproductive and bone abnormalities traced to phosphorus deficiency, Eckles, Becker, and Palmer in Minnesota; pica, Mareq in the Belgian Congo; phosphorus deficiency, Hart *et al.* in Wisconsin; and "stiffs" and "sweeny," Becker *et al.* in Florida. Most of these abnormalities seemed to be caused by common dietary defects and the studies made of them focused attention on mineral deficiencies as geographic area problems involving soil structure and fertilization and climatic conditions. However, not all of these troubles were caused by single dietary defects. "Bush sickness" was traced eventually to cobalt deficiency as the major cause, and the condition "lamziekte" observed by Theiler *et al.* was botulism resulting from the eating of infected bones, which, in turn, was a symptom of "stifziekte," the condition found to result from a deficiency of phosphorus. The condition known as "lechsucht" observed by the German workers, although in some cases it may have been complicated by a deficiency of phosphorus, was traced primarily to a deficiency of copper.

Symptoms of deficiency. In the meantime studies were being conducted between 1912 and 1935 by workers at the experiment stations in Iowa, Minnesota, Wisconsin, Michigan, Florida, West Virginia, and South Africa to determine the symptoms in cattle of uncomplicated deficiencies. In 1912 Rose at the New York Experiment Station reported that cows receiving a low-phosphorus ration became stiff in the joints and fell off in milk yield. Eckles and Swett in 1918 found that a heifer fed a low-calcium ration made normal growth to about 13 months of age, but at that time she became stiff in her joints and could get up only with

extreme difficulty. Becker in 1920 produced a rachitic condition in calves by feeding a low-calcium ration. After the discovery of vitamin D in 1922 and its role in mineral metabolism, the symptoms characterizing a deficiency of phosphorus and of calcium were more accurately described. The symptoms of a dietary deficiency of phosphorus were found to be: anorexia, depraved appetite, a reduction in the blood level of phosphorus; enlargement of the ends of bones and weak bones of low-ash content in growing cattle; decalcified, weak, and broken bones which, in some cases, cause paralysis due to nerve damage in mature cattle; stiffness; lameness; and infertility due largely to the inhibition of estrus. A deficiency of calcium results in essentially the same disturbances as that of phosphorus, except that the effect upon appetite is not as marked; the blood level of calcium is altered only under extreme deficiency conditions and, then, may be followed by tetany; and reproductive disturbances do not occur.

Allowances for growth. The results of experiments conducted at the Missouri Experiment Station between 1907 and 1927 revived the emphasis placed on the importance of adequate amounts of calcium and phosphorus in the ration of growing cattle. It was shown that young cattle provided just enough feed to maintain a constant weight continued to grow in height, length, and width of skeleton. In experiments with normally fed cattle, the percentages of calcium, phosphorus, and magnesium in the skeleton were found to increase as animals became older. Between 1925 and the late 1930's experiments were conducted by the experiment stations in Michigan, Pennsylvania, Minnesota, Wisconsin, Ohio, West Virginia, and South Africa which contributed to determining the minimum requirements for growth. From these studies the present-day allowances of calcium and phosphorus were developed. From birth to the time a growing animal weighs 1,000 lb., these range from 5 to 20 g. and from 4 to 15 g. per day, respectively.

Mineral balances of lactating cows and allowances for milk production. In 1909, Hart, McCollum, and Humphrey determined mineral balances for one milking cow. They observed that a negative balance of both calcium and phosphorus occurred when the milk yield was greater than 20 lb. per day but that the percentages of calcium, phosphorus, magnesium, and potassium in the milk remained constant over a wide range of intake of these elements. After these experiments, the metabolism of calcium and phosphorus by lactating cows was studied extensively by Forbes *et al.* (1916-1935), Meigs *et al.* (1919-1935), Hart *et al.* (1914-1932), Huffman *et al.* (1922-1935), Becker *et al.* (1925-1935), Ellenberger *et al.* (1931-1940), and by others. The results of the balance trials conducted continuously during long periods of time by Forbes *et al.* (1916-1922), which suggested that the balances of calcium and phosphorus generally are negative when the production of milk exceeds 10 lb. per day and that various supplements failed to effect positive balances, provoked many subsequent experiments. These revealed that during early lactation negative mineral balances exist but that during later lactation the balances become positive with the most intense storage of calcium and phosphorus occurring during the last 2 months of gestation. By 1930, the withdrawal and replacement of minerals in the cow's skeleton were considered to be a normal cycle of events. Although calcium and phosphorus balances were generally improved by supplementing rations with bone meal or calcium- and phosphorus-containing salts, negative balances were not always avoided during the peak production period. When nonlegume roughages were fed, larger negative balances were found than when the roughage was legume. However, by 1935, most authorities were agreed that there was not a general need for calcium and phosphorus supplementation. Also, under the usual conditions of management the mineral balances of dairy cows were not improved by vitamin D supplements, exposure to ultraviolet light radiations, or the feeding of glucose or hydrochloric acid. Palmer in 1928 showed that a high-magnesium ration increased the excretion of calcium and phosphorus by cows, particularly when the phosphorus content of the ration was low. Meigs in 1926 pointed out that rations low in calcium causing the mobilization of both calcium and phosphorus result in a wastage of phosphorus. Although the ratio of calcium and phosphorus in the diet had been found to influence the retention of these elements by small laboratory animals, Huffman *et al.* in 1933 and Du Toit *et al.* in 1938 found that the retention by mature cows and growing cattle, respectively, is not affected by the ratio between these elements when sufficient total amounts are provided. During the 1940's workers in Denmark and England demonstrated that the feeding of thyroprotein to cattle caused a rachitic-like condition in young animals and osteomalacia in mature cows.

During the 25-year period preceding 1935, most of the details of the metabolism of calcium and phosphorus in gestation, lactation, and growth known in 1956 were developed. Also, mineral and vitamin deficiencies were differentiated; the relationship of vitamin D to mineral nutrition was established; the relative unimportance of the distinction between the nutritive values of organic and inorganic compounds of mineral elements was decided; and the influence on the mineral well-being of animals of production and preparation treatments of feedstuffs was pointed out. The allowances of 10 g. each daily of calcium and phosphorus for the maintenance of a 1,000-lb. cow and of 0.9 g. of calcium and 0.7 g. of phosphorus per pound of milk produced as proposed in 1934

by Huffman are recommended in feeding standards in 1956.

Endogenous excretion. Studies of the true absorption of mineral elements have long been deterred by the lack of satisfactory methods for measuring the endogenous excretion. Although Aylward and Blackwood in 1936 had measured the endogenous excretion of minerals by cows, their method required fasting for 10 to 12 days. In 1951, Klieber *et* al. and, in 1953, Visek *et al.* employed radioactive phosphorus and calcium, respectively, to develop methods for the measurement of the endogenous excretions. The results of these studies indicate that the rate of excretion of endogenous minerals increases with age and/or size of animal and the dry matter intake.

Milk fever. Milk fever appears to have been noticed for several centuries but was first noted in the literature in 1793 by Eberhardt. As late as 1884 it was thought to be a congestion of the brain associated with the production of large quantities of milk after calving and, therefore, was called "parturient apoplexy." Possibly because milk fever is sometimes complicated by acetonemia, which is characterized partly by low levels of blood sugar, the so-called "hypoglycemic" theory was originated in 1923 by a Canadian veterinarian. The present-day approach to the treatment of milk fever stems from the belief of Dryeere and Greig in 1925 that the syndrome is caused by parathyroid insufficiency. During the same year, Little and Wright pointed out that milk fever is characterized by a low level of calcium in the blood and, in 1931, Seekles simulated milk fever symptoms by injecting oxalate. In 1933, Little and Mattick suggested that vitamin D might be fed as a preventive measure, and during the period 1946 to 1955, Hibbs, Pounden, and associates gave much attention to this possibility. As a result of their studies, the most effective means of preventing milk fever found by the Ohio workers involves feeding 5 to 30 million units of vitamin D per day for 3 to 7 days prepartum. Although Hibbs and Pounden had hoped that their treatment would activate the parathyroids by the time of parturition, their results suggest that the calcemic effect of vitamin D might be the result of an increased intestinal absorption of calcium. In 1954 and 1956, Boda and Cole reported that the feeding of low-calcium, high-phosphorus rations during the cow's dry period reduced the incidence of milk fever. This response is explained on the basis that a compensatory hypertrophy of the parathyroids is induced and sufficient calcium is mobilized to obviate a decline in the level of blood calcium at parturition and during early lactation.

Magnesium

Symptoms of deficiency. After Leroy's observation in 1926 that mice restricted to a low-magnesium diet failed to grow and died in about 30 days, McCollum and associates (1932, 1935) described the magnesium deficiency syndrome in rats and dogs. In 1935, Duncan, Huffman, and Robinson found that calves fed milk alone or with other concentrates but supplemented with iron, copper, and manganese developed a tetany characterized by low levels of magnesium and normal levels of calcium and phosphorus in the blood. Frequently the calves died while in a convulsive state and, on autopsy, showed calcified areas in the cardiovascular system. In 1941 Huffman *et al.* suggested that a daily allowance of 0.6 g. of magnesium per 100 lb. body weight is adequate. Further studies were made of magnesium deficiency by Thomas *et al.* in 1953 and by Blaxter *et al.* (1953-1955) using low-magnesium synthetic diets. The resulting tetany and hyperirritability now appears to be the result of a changed potential at the neuro-muscular junctions or a change in the activity of acetyl cholinesterase or choline acetylase. Blaxter and Rook (1955) found also that a dietary deficiency of magnesium causes an increased production of heat and a reduced retention of energy by calves.

Grass tetany. Sjollema in 1930 described a condition occurring in cattle in Holland which he called "grass staggers" and which has also been termed "grass tetany." The condition generally occurred soon after cows were turned to pasture and was characterized by twitching muscles, hyperirritability, tetanic contractions, and death during convulsions. In his early studies he found that many animals responded to calcium therapy. Later studies by Sjollema and Seekles (1932) showed that the blood levels of phosphorus are normal but those of calcium and magnesium are low. The condition affects males as well as dry or lactating females. Studies made in Holland and by Cunningham in New Zealand in 1936 showed that although the blood level of magnesium is low, the grass consumed by animals is generally of adequate magnesium content. As a consequence, it has been presumed that the magnesium of the grass is poorly available, particularly in the early spring. However, Garner in 1949 found that ruminal microorganisms and gastric juice in vitro release magnesium from grass. This led to the hypothesis that some alimentary disturbance may reduce the availability or absorption of magnesium. In 1955 Head and Rook, as a consequence of finding that the ammonia content of the rumen liquor and of the blood of cattle consuming early-spring grass is higher than that of cattle fed winter rations, attempted to alter the absorption of magnesium by administering ammonium acetate or carbonate via rumen fistulae to cattle consuming hay and concentrate rations. These treatments effected a lowering of the blood level of magnesium and reduced the urinary excretion of the element. Head and Rook suggest that hypomagnesaemia in cattle may arise from an interference in the absorption of magnesium by large

quantities of ammonia. The significance of Brouwer's finding in 1951 that the herbage of tetany-producing pastures is high in potassium relative to the amounts of calcium and phosphorus is undetermined in 1956.

Salt (Sodium Chloride)

Symptoms of deficiency and allowances. After studies of the salt requirements of cows were made by Babcock and Carlyle in 1905, this problem was not studied to any extent until the period of 1927 to 1934 when Theiler and his coworkers as a result of growth and performance trials recommended 1.5 g. of sodium and 5 g. of chlorine per day for growing cattle and 11 g. of sodium and 15 g. of chlorine per day for milking cows. Sheehy in 1936 found that calves fed a salt-deficient ration become unthrifty. The most extensive experiments on salt requirements were completed in 1952. At that time Smith and Aines reported that cows consuming a normal ration not supplemented with salt developed depraved appetites soon after the initiation of the treatment but maintained total feed intakes, milk production, and body weight for many months. After about 8 months, deficiency symptoms developed. These consisted of reduced appetite, sharp declines in milk yield and body weight, shivering of the musculature, lowered body temperature, cardiac arrhythmia, and hypertrophy of the adrenal glands. Although the composition of the milk was unaltered, the chloride content of the blood decreased and the sodium and chloride concentrations of the urine became nil. Clear-cut evidence was presented that sodium is more limiting than chloride. These studies show that 30 g. of sodium chloride per day in addition to that found in usual feedstuffs is an adequate allowance for cows producing as much as 14,000 lb. per annum.

Iodine

Symptoms of deficiency and allowances. After Courtois in 1811 accidentally discovered iodine in burnt seaweed and Fyfe in 1819 isolated it from sponge, Coindet in 1920, though not knowing that iodine had been found in sponge, postulated that iodine was the goiter-curing principle in burnt sponge. After the initial success in the treatment of goiter, over-zealous use of iodine resulted in toxicity, despite the caution issued by Coindet. In 1850 Chatin demonstrated a relationship between the incidence of goiter in various areas and the iodine content of the water and feedstuffs. Following the report in 1860 by Rilliet that iodine has adverse effects, the ensuing controversy continued until 1896, when Baumann found a high level of iodine in the thyroid gland. Marine and his coworkers in 1907 and 1908 demonstrated that the activity of the thyroid gland depends quantitatively on its iodine content. In addition they found that the young born of partially thyroidectomized mothers fed iodine-low diets were born with enlarged thyroid glands having a characteristically abnormal histology. In 1912 Martin in England found that animals had uniformly small thyroid glands of high iodine content, whereas Fenger in 1913 studying animals slaughtered in Chicago found that the glands of mature animals were of normal size and those of many fetuses were abnormally large and had low contents of iodine. In 1914, Kendall isolated the hormone, thyroxine. Between 1917 and 1930, Welch, Smith, Kalkas, Hart, Steenbock, Hadley, Bell, and others described "big neck" in cattle. These studies pointed to iodine deficiency as an area disturbance which, in the United States, was prevalent from the Great Lakes region to the Pacific Ocean. In 1927 McClendon reported the occurrence of iodine deficiency in many areas of the world. The results of these studies demonstrated that a deficiency of iodine in the maternal diet causes hyperplasia of the thyroid gland of the fetus. Thus, cows may produce stillbirths or weak calves having an obvious goiter. Iodine therapy does not always improve the health of the calf. The dietary significance of iodine, therefore, is in its preventive rather than curative value. Forbes *et al.* in 1932 found that iodine supplementation of iodine-adequate rations did not increase the growth rate of calves or affect the incidence of abortion in cows. Griem *et al.* in 1942 recommended an allowance of iodine equivalent to 0.0076% of the salt fed. This generally is sufficient to provide 2 to 4 γ of iodine daily per kilogram of body weight.

Feeding of thyroprotein. The findings that thyroidectomy depresses lactation (Grimmer, 1918) and growth (Simpson, 1924) suggested that mild hyperthyroidism might increase the rate of growth and milk production in cattle, which in 1934 was demonstrated by Graham. During the 1940's Reineke and Turner improved the iodination process, making it possible to prepare thyroid-active proteins of high activity. Also during this period, many workers studied the effects of feeding iodinated proteins to cattle. As a consequence, it was learned that the milk yield may be increased 20 to 25% and fat yield 20 to 50%. The response is greater in old than in young cows and during declining lactation than during peak lactation. Unless the level of feed intake is raised when thyroprotein is fed, cows lose weight markedly. The induced hyperthyroidism is accompanied by an increased heart and respiration rate. During the late 1940's workers in Britain and Denmark reported that the continuous feeding of thyroprotein caused a rachitic-like condition in young cattle and osteoporosis in mature cattle. In the early 1950's the Dairy Research Branch, USDA, reported on their long-time studies of the effects of feeding thyroprotein, in which they observed a reduction in the milk-production response during successive lactation periods. By 1956, it is recognized that the

feeding of thyroprotein as a general practice is contraindicated, particularly in breeding herds, but that under certain economic conditions and where a long productive life is of no consequence, it may be feasible.

Copper

Area problem. Hart *et al.* in 1928 presented the first proof that copper is an essential dietary substance when they demonstrated that it is used in the formation of hemoglobin. Neal, Becker, and Shealy in 1931 probably were the first to suggest that a deficiency of copper may occur naturally in grazing cattle. The "salt sick" condition which they found in Florida responded to iron and copper therapy but not to iron alone, but later Neal and Ahmann (1937) showed that at least one cause of this condition may have been a deficiency of cobalt. As early as 1915 a wasting syndrome termed "lechsucht" and characterized by anemia, anorexia, diarrhea and emaciation was recognized in cattle consuming forages in Northern Europe. In 1933, Sjollema established that the cause is a deficiency of copper and that the forage of "healthy" areas is higher in copper content than that of the lechsucht areas. Later, Sjollema and also Moore in 1938 showed that the copper level in the blood of affected grazing cattle is reduced to as little as one-fourth of that of healthy cattle.

Symptoms of deficiency. A condition in very young lambs called "enzootic ataxia" in Australia (Bennetts and Chapman, 1937-1942) and "swayback" in Great Britain (Dunlop and Wells, 1938; Innes and Shearer, 1940), in which demyelination of the central nervous system occurs has been found to be prevented by feeding copper to the ewe during gestation. The ewes were found to have a macrocytic, hyperchromic form of anemia. Dunlop and Wells found that calves born in the same areas as the "swayback" lambs were unthrifty and scouring but did not show the nerve lesions. In 1939 and 1942 Bennetts and Hall reported on a condition known as "falling disease" occurring in cattle grazing low-copper pastures in Australia. In this syndrome, anemia, depraved appetite, rough hair coats, altered hair color, outgrowths on bones, damaged kidneys and liver, staggering gait, and death were observed, but diarrhea was not always evident. Bennetts and coworkers continued to report on this problem until 1948.

Copper-molybdenum antagonism. In the meantime Ferguson *et al.* between 1938 and 1943 reported their studies of the previous decade concerning teart pastures. In 1937, spectrographic studies of teart herbage revealed that they contained much more molybdenum than "healthy" pastures. The observation that the scouring produced by teart pastures resembled that found in copper deficiency led Ferguson *et al.* to use successfully copper salts as a preventive and curative measure. In addition to suffering from diarrhea, animals grazing teart pastures were generally unthrifty and their hair coats changed color. These observations suggested an interrelationship between copper and molybdenum in the nutrition of cattle. In 1944, Cunningham described a condition in New Zealand as "peat scours" with which he associated reproductive difficulties in cows in addition to the other copper deficiency symptoms reported earlier. He indicated that scouring was not a constant finding except when the molybdenum content of the herbage was high. In 1946, Jamieson and Russell first reported the natural occurrence of a copper deficiency in cattle in Great Britain and in 1950 described copper pining in calves in which they observed the usual symptoms of this condition except that they did not find pica, anemia, skeletal lesions, or hemosiderin accumulations. The animals responded to copper therapy, but the pastures were not deficient in copper per se or excessively high in molybdenum. They suggested that there was an interference with copper metabolism.

A rickets-like syndrome in calves and fragile bones in mature animals attributable to a deficiency of copper was reported independently by Marston, Cunningham, and Davis in 1950 and 1951. Diets high in molybdenum but normal in copper content were found by Shirley *et al.* in 1951 to increase the excretion of phosphorus by cattle.

By 1956 a number of areas in various parts of the world had been located where either the copper supplementation of the feeds grown or copper fertilization of the soil resulted in a reduced incidence of the symptoms of copper deficiency and/or molybdenum toxicity. At this time the interrelationships of copper and molybdenum are receiving active study by many investigators. It is of interest that molybdenum in 1953 was found by three independent groups of workers to be needed for intestinal and milk xanthine oxidase.

Cobalt

Area problem. Thirty-nine years after Aston in 1896 observed in New Zealand cattle a wasting condition characterized by an anemia for which limonite was not always remedial, Underwood and Filmer in 1935 found that an iron-free extract of limonite had therapeutic value for this condition. The value of the extract was traced to its cobalt content, and, during the same year, Marston and Lines employed pure cobalt salts to effect cures of the condition, which had become known as "bush sickness," "coast disease," "wasting disease," "enzootic marasmus," and other names. Later, Askew, Dixon, and associates working in New Zealand during the period 1935 to 1937, confirmed these findings and showed that a deficiency of cobalt in the soil and in the plants grown thereon is the cause of the disease. It is striking that cows and sheep grazing "sick" pastures

are unthrifty and die while horses thrive on the same pastures. It became recognized that cobalt deficiency is limited to certain areas. After the observation in 1937 that such areas exist in Florida, others were reported during the 1940's in Western Canada, Michigan, Wisconsin, and New Hampshire and, during the 1950's, in New York and North Carolina. Undoubtedly the conditions observed in some areas are not due solely to a lack of cobalt but are due partly to a lack of copper.

Symptoms of deficiency. As a result of the earlier studies and the development of uncomplicated cobalt deficiency disease by Hale *et al.* in 1950 and by Cornell workers in 1951 the following symptoms have been observed: anorexia; loss of weight ; a normocytic, normochromic anemia, and the deposition of hemosiderin in the spleen. It was found that in order for cobalt to be effective it has to be ingested, but only extremely small amounts are required.

Cobalt-vitamin B_{12} interrelationship. In 1948 after the isolation of vitamin B_{12}, it was revealed that cobalt constitutes a small proportion of the molecule of this vitamin. In 1950 Hale *et al.* demonstrated that there is much less of vitamin B_{12} in the ruminal ingesta of cobalt-deficient sheep than in that of cobalt-supplemented sheep. Smith *et al.* in 1951 showed that the injection of liver extracts had a curative effect on cobalt-deficient sheep which was lost when the vitamin B_{12} in the extracts was destroyed. Crystalline vitamin B_{12} has a maximum effect when injected, but it is much less effective when ingested. These findings were verified in 1952 by Marston. Thus, a deficiency of cobalt is primarily a deficiency of vitamin B_{12}. However, for practical purposes this disease is treated more economically by the use of cobalt, for which cows have a need of about 0.5 mg. per day, than by vitamin B_{12}.

Fluorine

Toxicity. The toxic effect of fluorine was known long before 1880, but it was not recognized as a serious problem in the feeding of livestock until 1912. In that year, Bartolucci and, in 1926, Cristiani and Gautier found that the vegetation in certain areas contained enough fluorine to cause cachexia in grazing cattle. The fluorine absorbed by the plants was traced by these workers and others to contamination of the atmosphere by nearby industrial plants processing superphosphate, glass, aluminum, and other products. In 1929 and 1930, Taylor, Reed, and Huffman found that concentrate rations containing 1.5% of rock phosphate were injurious to cattle, causing anorexia, abraded teeth, and exostoses of the long bones and mandibles. These workers traced the cause of these symptoms to fluorine. Between 1932 and 1935 extensive studies of fluorine toxicity were conducted by Phillips *et al.* at Wisconsin. It was found that a daily intake of 1 to 2 mg. of fluorine per kilogram of body weight did not affect growth but that 3 mg. or more retarded the growth of heifers and caused marked reductions in the milk yield and body weight of cows. Chemical and biological studies suggested that the fluorine content of the milk is not increased by feeding. Fluorine toxicity does not effect functional failure of the reproductive processes, though estrus after parturition is delayed and the birth weight of calves is slightly less than normal. Phillips *et al.* suggested that fluorine attacks enzyme systems involved in cellular respiration. In 1942, Cohrs found that chronic fluorosis caused osteoporosis in calves and exostoses in older cattle. Since the 1930's, when it was learned that fluorine toxicosis occurs when cattle consume concentrates containing as little as 0.62% of raw rock phosphate, this material has been used as a mineral supplement for cattle only after defluorination. Becker *et al.* in 1950 found that the symptoms of fluorosis were alleviated by feeding alum. In 1956, studies, particularly by Hobbs and associates in Tennessee, were being continued to define more accurately the tolerance levels for cattle of fluorine fed over long periods of time.

Selenium

Toxicity. Although Japha in 1842 showed that selenium is toxic to animals and Cameron in 1880 found that plants would absorb it from the soil, it was not associated with "alkali disease" until 1931. As early as the 1850's a dyserasia in which cattle (and other animals) became unthrifty, lost hair and hoofs, developed a staggering gait and eventually died was observed in the Great Plains and Rocky Mountain regions. This malady, which the pioneers called "alkali disease," seemed to be associated with forage plants. It was not until 1913 that the South Dakota Experiment Station concluded that the term "alkali disease" is a misnomer because alkaline waters had not been found to be harmful to animals. Also at that time, it was concluded that the disease is not due to plant alkaloids or glucosides. In 1922, Hutton, who had surveyed the soil of affected areas in South Dakota, believed that the condition is associated with certain soil types. By 1927, chemical studies had not revealed any toxic substances although the feeds tested were known to be toxic to animals. In 1931, however, Robinson found selenium present in the protein fraction of grain with which Franke had produced toxicosis in rats. It followed that the addition of selenium to nontoxic diets produced the "alkali disease" symptoms. As a result of the efforts of these workers and of Beath *et al.* and Moxon *et al.*, symptoms of the condition had been outlined by 1937. In addition to those mentioned above, the symptoms are: anemia, erosion of bones, stiffness, blindness, flabby hearts, cirrhotic livers, and generalized pathology. Some of the symptoms resemble those found in avitaminosis A. Selenium was found to be secreted into the milk in sufficient quantity

to poison calves. Chronic toxicity in cattle is caused by rations containing only 8 p.p.m., whereas acute toxicosis may result from the ingestion of rations containing 500 p.p.m. In 1944, Moxon *et al.* found that 25 parts of sodium arsenite per million parts of salt afforded cattle considerable protection from selenium toxicity. This approach to prevention was the result of studies made between 1935 and 1940 which showed that the injection glutathione protects rats from selenium toxicity and that arsenic appears to protect sulfhydryl compounds from attack by selenium. In 1951 Walsh *et al.* found selenium toxicosis in cattle consuming forage grown in certain areas in Ireland.

VITAMINS

Vitamin A

Discovery. In 1913 vitamin A was discovered independently by McCollum and Davis and by Osborne and Mendel, who were studying the nutritive qualities of various fats for rats fed purified diets. The superiority of butterfat was attributed to vitamin A, which McCollum and Davis in 1914 found in the unsaponifiable fraction. Having associated the yellow color of plant fats with the vitamin A effect, Steenbock in 1919 demonstrated that carotene, but not xanthophyll, has vitamin A activity. This was not accepted at the time and, as a consequence, Palmer in 1919 and others began studies which revealed more than twenty substances, which became known as the carotenoid pigments. Final proof that carotene is converted to vitamin A in the body was provided in 1929. In the meantime a dietary deficiency of vitamin A was shown to cause degenerative changes in nerve tissue (E. B. Hart and McCollum, 1914), a generalized condition in which the normal epithelium in glands and mucous membranes is replaced by stratified keratinized epithelium (Wolbach and Howe, 1925) and visual disturbances (Holm, 1925).

In 1911, E. B. Hart, McCollum, Steenbock, and Humphrey reported on their experiments in which single plants (corn, wheat, oats) had comprised rations containing all nutrients known to be essential at that time for growing cattle. After one year the rate of growth was about the same for the heifers of all groups. But later the heifers fed the wheat plant either aborted or produced stillbirths or calves that died soon after birth; they also yielded considerably less milk than the heifers fed the other plants. Blindness also was found in the newborn calves. Not having been able to explain these results on the basis of their chemical studies of the feed, excreta and tissues of the calves, the Wisconsin workers concluded that wheat must carry toxic factors or, possibly, lacks something provided by corn. These studies were continued and, in 1924, in reevaluating their earlier findings, these workers concluded that the failure of the wheat ration is explained on the basis of its low vitamin A and calcium contents. Eckles in 1924 also attributed stillbirths and the birth of blind calves to a deficiency of vitamin A. It was not until 1926, however, that Jones, Eckles, and Palmer demonstrated that vitamin A is indispensable for the growth and well-being of calves. Blindness in heifers fed cottonseed meal was prevented by Reed *et al.* in 1928 by feeding vitamin A. In 1933, G. H. Hart and Guilbert discovered vitamin A deficiency in cattle under range conditions.

Avitaminosis A. By 1933 it became clear that a deficiency of vitamin A in the ration of cattle resulted in excessive lacrimation, xerophthalmia, occasionally complete blindness, anorexia, diarrhea, pneumonia in calves, stillbirths, birth of weak and blind calves, abortions during the latter half of gestation period, anestrus for several months after calving, keratinized vaginal epithelium, nephritis, edema, and sclerotic livers. Later Moore (1935) produced blindness in calves resulting from a constriction of the optic nerve caused by stenosis of the optic foramen but, in 1941, he was not able to produce this effect in mature cows. In 1936 Moore and Hallman observed "white spotted" kidneys in calves deprived of colostrum. Moore described papilledema caused by increased intracranial pressure in calves (1937) but found it difficult to develop in cows (1941). Moore and Sykes (1940) had demonstrated that the cerebrospinal fluid pressure in calves increases in avitaminosis A. From 1940 to 1947, Sutton, Erb, Hodgson, and Jones and their coworkers studied the effects of vitamin A deficiency on the bull. The results of these tests showed that spermatogenesis was impaired, but often viable semen was produced by partially blind bulls too weak to mount the cow. Vitamin A therapy was found to effect repair of the germinal epithelium if the deficiency was not too severe. Accompanying other symptoms of avitaminosis A in the bull is the occurrence of cystic pituitary glands.

Dietary sources. It had been known even long before the discovery of vitamin A that fish liver oils cured night blindness. The research during a 20-year period stimulated by Steenbock's association in 1919 of the yellow pigments of plants with vitamin A pointed to the value of plant sources. These studies generally showed that roughages prepared from legumes are better sources of carotene than those from nonlegumes, though the potency of both kinds of plants declined with the advancement of growth stage. In 1929 Russell focused attention on the influence of forage curing methods when he demonstrated that large losses of carotene occur when hays are exposed to rain and sunlight. Experiments conducted from that time through the 1940's showed that forages ranked in order of decreasing content of carotene as follows:

green forage or pasture, silage, barn dried hay, and field cured hay.

Amount in milk. By 1940 it was well established that the vitamin A activity of milk depends to a considerable extent upon the carotene intake and that the Channel Island breeds are less efficient converters of carotene to vitamin A than are Holsteins, Ayrshires, or Brown Swiss as evidenced by the relatively high-carotene, low-vitamin A content of their milk. It was known though that human beings could convert carotene to vitamin A. At that time the liver was considered to be the site of conversion because T. Moore in 1929 had found a large amount of vitamin A relative to that of carotene in the liver, and Olcott and McCann in 1931 had demonstrated the presence in the liver of a carotenase. Despite unsuccessful attempts to demonstrate the conversion in vivo, this was accepted until 1947 when Deuel and his coworkers suggested that the intestinal wall may convert carotene to vitamin A. In 1949, Thompson *et al.* demonstrated that the major site of conversion is the wall of the intestine in rats and pigs. Owen *et al.* in 1951 demonstrated this also with cows.

Placental and mammary transfer and carotene allowances. In the early 1930's it was known that cow's colostrum has as much as 70 times the vitamin A activity of normal milk (Dann, Semb *et al.*) and that the vitamin A reserves of the newborn calf are extremely low (Guilbert and G. H. Hart). This suggested the great importance of prepartal and neonatal nutrition. During the late 1940's workers in many parts of the world demonstrated that the vitamin A content of colostrum and of the body stores of the newborn calf could be increased by feeding prepartal rations of high vitamin A activity. Extensive experiments conducted between 1945 and 1950 indicated that no advantage is gained in the control of calfhood diseases by feeding as supplements a variety of vitamins, including vitamin A, when calves receive the usual amounts of colostrum, whole milk, and roughage of adequate quality. The present-day allowances of 6 mg. of carotene per 100 lb. of body weight per day for cows and calves recommended by Morrison and the National Research Council Committee were derived from the studies conducted by Converse *et al.*, 1936; Krauss *et al.*, 1939; Guilbert *et al.*, 1940; Moore *et al.*, 1939-1944; Phillips *et al.*, 1941; Kahlman and Gallup, 1942; Keener *et al.*, 1942; Boyer *et al.*, 1942; Keyes *et al.*, 1943, and others.

Vitamin D

Discovery. Long before the discovery of vitamin D, cod liver oil had been known to cure rickets, and Palm in 1890 proposed that rickets is caused mainly by a deficiency of sunlight. In 1922 as a result of destroying the vitamin A in cod liver oil, McCollum was able to show that, although the oxidized oil could not cure xerophthalmia, it would cure rickets. After Huldschinsky's finding in 1919 that ultraviolet light has a curative effect upon rickets, much attention, particularly during the 1920's, was given to the activation of a variety of sterols which were found to have anti-rachitic activity. In 1922 McCollum proposed the "line test" for the assay of the vitamin D value of feedstuffs.

Avitaminosis D. From 1927 through the late 1930's numerous reports, particularly by the Pennsylvania, Michigan, and Wisconsin Experiment Stations, dealt with the essentiality of vitamin D in the diet of dairy calves. These experiments demonstrated that calves kept in the dark and consuming rations low in vitamin D have a slow rate of growth, bones with enlarged ends and low ash contents, bowed legs and backs, and, occasionally, slight paralysis of the rear quarters due to vertebral fractures. The serum concentrations of calcium and phosphorus decrease and tetany sometimes occurs. In 1936 Bechtel *et al.* reported their excellent study of the detailed histological changes occurring in rickets and those occurring during its cure. Cod liver oil, ultraviolet light irradiation of calves directly or of the feed consumed, and exposure of calves to direct sunlight were found to be both preventive and curative. In 1927 Gullickson and Eckles had reported that calves confined in the dark but fed adequate rations, remained healthy for as long as two years. Duncan and Huffman found that high intakes of viosterol are harmful and eventually kill calves.

Dietary sources. During the 1930's attention was given to evaluating various natural feedstuffs as sources of vitamin D. In the late 1920's Morrison and Rupel had stated that calves getting a good ration, particularly when fed legume hay, do not benefit from sunshine or cod liver oil supplementation. Bechdel *et al.* in 1933 found that the antirachitic value of alfalfa hay is due to its vitamin D, and not to its ash, content. They showed also that oat straw has considerable antirachitic activity, which is greatly reduced by cold ether extraction. Bechtel *et al.* in 1936 found that corn silage has as much as 40 I.U. of vitamin D per pound, largely concentrated in the tassels, silk, and husk. Sun-cured hays generally have several times as much activity as the same forage artificially dried. Though in 1933 it had been reported that hay harvested and dehydrated at night has practically no vitamin D value, research conducted at the Vermont Station in 1949 suggests that hay prepared in this way has considerable antirachitic activity. Also, in 1949, workers at Beltsville found that, although they have less vitamin D value than sun-cured hay, barn-cured hays and wilted silages contain appreciable quantities. The amount of dead leaves on plants appears to determine the vitamin D value of artificially dried hays and unwilted silages.

Placental and mammary transfer and allowances for growth. The placental transfer of vitamin D as determined by the storage in the liver and the concentration in the blood of the newborn calf is not very great (Dutcher and Guerrant, 1938, and Eaton *et al.*, 1947), but Eaton *et al.* found that the amount in the colostrum can be increased by feeding the dam 100,000 I.U. per day for 8 weeks prepartally. Also, a single massive dosage administered to the young calf increased by 10-fold the amount of vitamin D in liver. From the practical feeding standpoint, special attention must be given to vitamin D supplementation when calves are not consuming much hay and are not exposed to sunlight, but are consuming rations comprised largely of concentrates and milk. During the 1930's work conducted at the Pennsylvania and Michigan stations led to the present-day recommended allowance for growing calves of 200 to 400 I.U. of vitamin D per day per 100 lb. of body weight.

Needs of cows. By using a ration devoid of usual roughages and by keeping cows out of sunlight, Wallis in 1938 was able to reduce the serum levels of calcium and phosphorus and to develop stiffness in mature lactating cows. However, a deficiency was not evident in high-producing cows until after 4 months and, in poorer producers, until after 8 months. Brief exposure to sunlight or feeding as little as 2 lb. of sun-cured hay per day effected a rapid recovery. Therefore, in retrospect, it is not surprising that E. B. Hart and associates were not able to improve the calcium and phosphorus balances of lactating cows fed normal rations by supplementing these rations with cod liver oil, irradiated yeast, and sun-cured hay or by irradiating the cows with ultraviolet light.

Amount in milk. Between 1935 and 1945 many studies were made of factors influencing the vitamin D content of milk. Cows of the high-fat breeds were found to produce milk of higher vitamin D content than those of low-fat breeds. The milk of cows fed rations low in vitamin D and not exposed to sunlight contained less vitamin D than that produced by cows exposed to sunlight. Summer milk, therefore, is more potent than winter milk. However, only massive intakes of vitamin D will raise the concentration above that in summer milk. Henry, Kon, and associates in 1937 showed that the high vitamin D content of milk produced by cows on pasture is due to sunshine only.

Vitamin E

Muscle dystrophy. Abnormalities described as "fish flesh," "leg illness," "calf rheumatism," and "white meat" in cattle in Germany, Norway, and France during the late 1800's now appear to have been the result of avitaminosis E. In 1925 Slagsvold reported the occurrence of muscle dystrophy in calves fed cod liver oil, and in 1926 Agduhr produced the condition in both heart and skeletal muscles in other animals. In 1931 Pappenheimer and Goettsch described in detail dystrophic changes in the muscles of rabbits and the development of dystrophy during prenatal life. Although they attributed the condition to a nutritional cause, they did not ascribe it to vitamin E. Cod liver oil was a component of the diet used. Beginning in 1932, Maynard, McCay, and Madsen *et al.* attempted to formulate a diet of purified constituents for herbivorous animals. During the course of these studies they produced muscle degeneration in rabbits, guinea pigs, goats, and sheep which they eventually traced to cod liver oil as the cause. In 1935, they found that the saponifiable fraction of cod liver oil also produced the condition and, in 1938, McCay *et al.* showed that hydrogenation of fish liver oils eliminated their dystrophic activity. Although cod liver oil was found to be toxic to other herbivorous animals, the Cornell workers in 1936 and Gullickson and Fitch in 1944 were not able to effect muscular dystrophy in calves by using it. Hjarre and Lilleengen in 1936 and Blaxter *et al.* in 1952 produced muscle degeneration by feeding calves a skimmilk diet containing very large amounts of cod liver oil. Between 1930 and 1935, Hjarre and Lilleengen and Slagsvold and Lund-Larsen and, in 1947, Vawter and Records studied muscle dystrophy occurring naturally in cattle. As a result of these studies and those of the induced condition, the nature of muscle dystrophy has been worked out. Under natural conditions it occurs most often in calves 3 to 10 weeks old and is characterized by a stiff gait, muscular pain, abnormal heart action, and prostration. White areas and zenkers degeneration may be found in the heart and skeletal muscles. The amounts of calcium, sodium, and nucleic acids in dystrophic muscles were found by Blaxter *et al.* in 1952 to be greater than those in normal muscles. In experiments reported between 1944 and 1949, Gullickson *et al.* fed continuously for several years to cows and bulls rations sufficiently low in vitamin E to cause sterility in rats. After several years, a good many of the animals died of cardiac failure as a result of damage to the myocardium, but no other indications of ill health were observed.

Reproduction. Ever since 1922 when Evans and Bishop produced sterility in rats by feeding a diet deficient in vitamin E, attempts have been made to remedy reproductive disturbances in other animals by feeding this vitamin. Evans in 1936 isolated α-tocopherol from wheat germ. In 1935 Henke found that the feeding of vitamin E concentrates to cows of irregular breeding behavior was without beneficial effect. Salisbury in 1944 found that the addition of vitamin E to the usual ration did not affect the character of the semen or the level of fertility of bulls. Both bulls and cows fed a ration low enough in vitamin E to produce sterility in rats are fertile and maintain normal reproductive functions (Gullickson *et al.* 1944, 1949).

Placental and mammary transfer. During the 1940's Parrish and coworkers demonstrated that the tocopherol level in the blood of the cow and of the newborn calf and in the colostrum can be increased by feeding tocopherols to the cow during her dry period. The blood level of the newborn calf was found to be about 15% of that of the cow. In 1948 and 1949, Loosli *et al.* and Krukovsky *et al.* reported that the milk of cows on pasture contains a greater concentration of tocopherols than that of the same cows receiving barn feeds. They also pointed out the protective value of tocopherols against the development of oxidized flavors in milk. In view of the antivitamin E action of cod liver oil, it is interesting that Golding, Soames, and Zilva in 1926, Petersen in 1932, and Whiting *et al.* in 1949 found that the feeding of cod liver oil depressed the percentage of fat in milk. This effect was traced in 1935 by McCay and Maynard to the saponifiable fraction. During the late 1940's Moore found that the same daily amount of cod liver oil administered in small dosages did not affect the fat test. Whiting *et al.* (1949) showed that cod liver oil also depressed the level of tocopherols in the blood.

The information available in 1956 suggests that although manifestations of avitaminosis E (notably dystrophy in calves) may occur under natural conditions, a deficiency under usual conditions of feeding is unlikely to occur, particularly if the ration consists of whole cereal grains and roughages.

Vitamin K

Dicumarol–vitamin K antagonism. In 1925 it was found in Canada and North Dakota that cattle consuming spoiled sweet clover hay often bled to death. It was recognized early that the bleeding condition is not caused by pathogenic organisms or by nutritional deficiencies. No alterations were found in the blood vessels, but spontaneous hemorrhages occurred in any part of the body. Although all factors believed to be needed for the normal coagulation of blood, such as fibrinogen, calcium, and platelets, seemed to be normal, the disease was characterized by a delayed coagulation time which pointed to a reduced prothrombin activity. In 1929 Dam found that an ether-extracted diet caused hemorrhages in chickens, which was the first observation of the symptoms now attributed to a deficiency of vitamin K.

Preliminary experiments at Wisconsin suggested that coumarin might be involved in the formation of the hemorrhagic substance. In 1937 Roberts and Link and in 1938 Smith and Brink found that coumarin added to low-coumarin hay which then was allowed to spoil resulted in a hemorrhage-producing hay. In 1941, King *et al.* found that the hemorrhagic condition is caused by a deficiency of vitamin K induced by a toxic substance and, during the same year, Campbell and Link crystallized the substance which was finally characterized, also during the same year, by Link and his coworkers as 3,3′methylene-bis (4-hydroxycoumarin) or dicumarol. Presumably in the spoiling of sweet clover hay, coumarin is oxidized to 4-hydroxycoumarin, two molecules of which are subsequently condensed with formaldehyde to form dicumarol. The fact that dicumarol administered to a live animal prolongs the coagulation time although its addition to drawn blood does not affect the clotting time suggests that dicumarol suspends the synthesis of prothrombin. Dicumarol is antagonistic to vitamin K but, as demonstrated by Link and his associates in 1942, this effect is not connected, in the hemorrhagic sweet clover disease, with the action of ruminal or gut microorganisms because dicumarol has the same effect when administered parenterally. Also, the addition of vitamin K to the diet overcomes the hemorrhagic effects of dicumarol by increasing the prothrombin level of the blood. Normally the vitamin K intake of mature cattle does not require special attention since Goss and coworkers during the early 1940's demonstrated that it is synthesized abundantly in the rumen.

B-Complex Vitamins

Ruminal synthesis. Having fed cattle for long periods of time without ill effects rations consisting of polished rice, hay, and oat straw which had been heated under pressure, Theiler *et al.* in 1915 postulated that the needs for B-complex vitamins were so low that they might be met by ruminal synthesis. In 1926 Bechdel, Eckles, and Palmer found that a ration sufficiently low in the B-complex vitamins to cause death within a few weeks in rats to which it had been fed would support normal growth in calves, which, when mature, reproduced normally. In 1928 Bechdel *et al.* fed rats a B-complex deficient ration supplemented with ruminal ingesta taken from a cow consuming a ration that was deficient in the B-complex vitamins. These rats grew much more rapidly than their controls consuming the unsupplemented deficient ration. These findings provided further evidence of the synthesizing character of the cow's rumen. At that time it was not definitely known that "vitamin B" is of a multiple nature, though this was established by 1930. By 1940, all of the presently known B-complex vitamins except folacin and vitamin B_{12} were recognized.

During the period of 1939 to 1943, workers at the Wisconsin, California, and Ohio Experiment Stations demonstrated that the following vitamins are synthesized in the rumen: thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, and biotin. Some indications were presented that the composition of the diet may influence the extent of synthesis. Cornell workers in 1940 found that the addition of yeast or liver to a ration deficient in riboflavin did not affect the growth rate of calves and in 1941 reported that the secretion of riboflavin in the milk is independent of the riboflavin intake.

These findings suggested that the B-complex vitamins are not dietary essentials for dairy cattle.

Nature of avitaminoses. As a result of having developed a purified diet for calves, a group of Illinois Experiment Station workers were able during the period from 1946 to 1954 to demonstrate the essentiality of certain of the B-complex vitamins. They found that the following vitamins are at least metabolic essentials and, under their restricted conditions, are dietary essentials during the first few weeks of life: biotin, pantothenic acid, riboflavin, thiamine, pyridoxine, and choline. In their first experiments, niacin was not found to be essential, presumably because it was synthesized in sufficient amounts from tryptophane. In 1954 Hopper and Johnson produced a niacin deficiency by adjusting the tryptophane level of the diet to 0.17%. The most striking symptoms of deficiency other than anorexia and retarded growth noted for the various vitamins were: biotin, paralysis; pantothenic acid, leg weakness; riboflavin, hyperemia of buccal mucosa and excessive lacrimation, but no corneal or lens defects; thiamine, weakness, incoordination, and convulsions; pyridoxine, epileptiform fits; choline, leg weakness, hemorrhagic kidneys, and fatty livers; and niacin, scouring, and dehydration. Under the usual conditions of feeding, calves do not benefit from B-vitamin supplementation. Warner and Sutton in 1948 used a photolyzed milk diet to demonstrate that young calves require riboflavin. Since mature ruminants synthesize an abundance of the B-complex vitamins, they require no special feed supplements. However, the findings of Weswig *et al.* in 1946 that bracken poisoning in cattle is caused by an antithiamine substance suggests that under certain conditions it may be necessary to give special consideration to this group of vitamins in the feeding of even mature cattle.

Bracken poisoning and thiamine deficiency. During the early 1950's considerable attention was given to bracken poisoning. Some of the results suggest that not all of the symptoms are explained by the presence of a thiaminase. In some cases bracken causing thiamine deficiency in the rat caused death in cows, and death was not prevented by the injection of thiamine. Pathologic changes in the bone marrow and aplastic anemia have been observed in bracken-poisoned cows. Thiamine usually disappears from the urine, but only terminally does pyruvic acid appear in the blood and urine of cows. Young plants are more toxic than older ones and the toxicity is destroyed by heat and eliminated by alcohol extraction.

RUMINAL DIGESTION AND SYNTHESIS

Maintenance of reaction and medium. Although many significant contributions to the biochemistry, physiology, and mechanics of rumen function which cannot be detailed here were made during this semicentennial period, an attempt will be made to sketch some of the historical landmarks having nutritional significance. The early studies of Lassaigne (1852), Colin (1852-1886), and Pavlov (1890-1910) showed that cow's saliva is almost entirely water. As a consequence, as recently as 1910 Pavlov felt that the role of saliva in digestion is mainly that of a solvent and lubricant. Later, Schwarz (1924), Schwarte (1939), and Wise *et al.* (1940) reported that the pH of calf's saliva is 8.1 to 8.2 and Chrzaszcz and Schechtlowna (1930) and Reid and Huffman (1949) found that cow's saliva has a pH of 8.5 to 8.9. In addition, saliva is an effective bicarbonate buffer; Colin in 1852 found that the secretion during a 24-hour period contains the equivalent of 300 g. of sodium bicarbonate. He in 1852 and Scheunert and Trautmann in 1921 found that depriving cattle of saliva caused death, which the workers in 1931 found to be the result of acidosis. In 1913, Zuntz stated that the total base in saliva is six times as great as that of the blood. Although the pH and buffering capacity of saliva are regarded to be the major factors maintaining the pH of the rumen ingesta between 5.8 and 7.8, as reported by Monroe and Perkins in 1939, Hale *et al.* in 1940, Olson and Smith both in 1941, Hastings in 1944 pointed out that the products of fermentation also contribute to maintaining a reaction of the ruminal ingesta which is compatible with the growth of microorganisms. In 1945 Danielli *et al.* found that as fermentation proceeds after the ingestion of a meal, the amount of free acid present increases in relation to that of the combined acid but, since free acid is absorbed from the rumen more rapidly than combined acid, another mechanism for the control of the reaction within the rumen exists. Other properties of cow's saliva, such as its considerable chemical reducing ability, adsorption capacity and low surface tension and its chemical composition, have been recorded. This information became useful during the last 15 years in determining artificial environments for studying ruminal microorganisms.

Microbial agents. Although since 1855 the digestion of fiber had been attributed to the action of agents other than secretions of the gastro-intestinal tract and beginning about 1880 some workers believed it to be the result of microbial activity, this was not demonstrated by direct microscopy until 1918 by Haberlandt and again in 1922 by Henneberg. During the 1920's and 1930's further attention was given to the ruminal microorganisms, particularly by Ankersmit, Henneberg, Baker, Becker, Winogradow, Mangold, and Fantham and their associates. These studies revealed that the microorganisms constitute a very complex population and are mainly bacteria and protozoa with some yeasts. Much effort was given to the ciliated protozoa and iodophilic bacteria. By 1940, however, it was resolved that the bacteria are

the chief cellulose-digesting organisms and that, largely as a result of the studies of Becker in 1928 and Mangold in 1929 demonstrating that cellulose digestion proceeds normally in defaunated animals, the protozoa are relatively unimportant. Van der Wath and Myburgh in 1941 also drew this conclusion. The glycogen-like material deposited in the bodies of protozoa was believed to be the result of ingestion by the protozoa of starch and starch-containing bacteria (iodophiles). In 1942, however, Hungate found one species of *Diplodinia* which produces an enzyme capable of converting cellulose to reducing sugar. In 1928 Bechdel *et al.* isolated and named an organism capable of synthesizing at least one of the B-complex vitamins. Propionic acid-producing bacteria were described by Elsden in 1945 and by Johns in 1951, and, also in 1951, Gall isolated lactic acid-producing bacteria. Cellulose-digesting bacteria have been studied by Baker *et al.* (1936-1947), Kohler (1940), Hungate (1943-1955), Bortree (1943-1949), Sypestyn (1949-1951) and Doetsch (1947-1956), Smith, Salsbury *et al.* (1950-1956), and others. By 1956 workers in many laboratories were engaged in isolating, characterizing, and naming the microorganisms indigenous to the rumen.

Development of methods of study. Most of the present knowledge of ruminal microorganisms has been gained since 1940. Much of the success in this work is the result of developments in methodology. The in vivo technique involving the use of animals with ruminal fistulae was used to demonstrate that, in the rumen, nonprotein nitrogen is converted to protein (Schwarz and Steinlechner in 1925; Mills *et al.* and Wegner *et al.*, 1941), 70 to 80% of the total digestion of cellulose occurs (Hale *et al.*, 1940, and Gray, 1947), ascorbic acid is destroyed (Knight *et al.*, 1940), cobalt is concentrated in microorganisms (Tosic and Mitchell, 1948), amino acids are synthesized (Loosli *et al.*, 1949), and that certain B-complex vitamins and vitamin K are synthesized (Wisconsin, California, Ohio, and Michigan workers, 1939-1951). Although some of these and other functions of the rumen had been shown by other means previously, these findings directly implicated the ruminal microorganisms. Contributions were made between 1935 and 1956 to the cultural methods of studying microorganisms by Becker, Baker, Hungate, Elsden, Bortree, Gall, Huhtanen, Doetsch, and others. Though Henneberg and Stohmann used the "artificial" rumen before 1885 when they pointed out that the fermentation processes in vitro are different from those in vivo, and Woodman *et al.* used a similar technique in the late 1920's, this approach was revived during the 1940's by Wegner *et al.* and Lenkeit and Becker and is being employed by many workers in 1956.

Digestion of fiber and liberation of energy. Most of the presently known products of digestion were recognized before 1906, and some German workers, particularly, had theorized that certain products, such as the short-chain fatty acids, contributed to the benefit of the host animal. In 1912 Pringsheim reported that cellulose digestion yields glucose, and Woodman *et al.* having made the same observation in 1928 suggested in 1930 that glucose is the main end product of value which is absorbed by the host. According to Woodman's view, the fatty acids were waste products of fermentation. Between 1935 and 1938 Pochon isolated organisms with which he demonstrated in vitro that the digestion of cellulose proceeds to the lower fatty acids. Also in 1938, Woodman and Evans abandoned their earlier view when they reported that fermentation goes beyond glucose to pyruvate, lactate, and, finally, to acetic and butyric acids, but they did not suggest whether these products were of value to the host. In 1939, Baker presented the possibility that glucose derives from microbial action on cellulose because he had observed the erosion of plant tissues by iodophiles and suggested that glucose as an end product enters the body of bacterium and is condensed to form a starch-like polysaccharide, thus explaining the staining reaction with iodine. The significance of the fatty acids, however, remained undetermined. In 1942 Phillipson *et al.* found that a relation exists between the concentration of the short-chain fatty acids in the ruminal ingesta and the ingestion of feed and that very little of these acids is found in the abomasum, suggesting that they might be absorbed from the reticulo-rumen and omasum. In 1933 Trautmann and Schmitt had been the first to demonstrate that absorption from the rumen is possible, by employing alkaloids. In 1944, Barcroft *et al.* showed that despite the fact that the mucosa of the rumen, reticulum, and omasum has stratified squamous epithelium, the blood draining these stomach compartments is higher in acetic, propionic, and butyric acids than the peripheral blood. Though some fatty acid was absorbed from the caecum, very little was absorbed from the abomasum and small intestines. These studies were greatly aided by the development of partition chromatographic methods by Elsden based upon the principles employed by Martin *et al.* in 1944. In 1947 Phillipson and coworkers suggested that a considerable proportion of the energy needed by cattle could be contributed by the fatty acids resulting from cellulose digestion. In 1951, McClymont and Popjak, Cowie, Folley, Glascock, Duncombe, and others reported that the mammary gland tissue of ruminants is superior to that of nonruminants in its ability to use acetic acid as a metabolite for the synthesis of fatty acids, particularly those of short chains. These workers also showed that about half of the fat in cow's milk can result from acetic acid reaching the mammary circulation. During the 1950's, workers in many laboratories were studying the metabolism of the fatty acids in relation to the diet, their

value as energy sources, and with respect to diseases characterized by ketosis.

Synthesis of protein from nitrogen. In addition to decomposing complex substances which otherwise would be valueless to the host, the microorganisms of the rumen are capable of effecting syntheses. This was recognized beginning with the studies of Weiske *et al.* in 1879 when it was observed that the nitrogen of asparagine was apparently utilized by ruminants. Zuntz in 1891 was probably the first to suggest that soluble amides might be used as a dietary substitute for protein, and Hagemann in 1891 appears to be the first to suggest that the protein formed in the bodies of microorganisms from nonprotein nitrogen might be digested in the lower part of the gastro-intestinal tract. Despite considerable study, particularly by German workers, the use of nonprotein nitrogen by ruminants was not generally recognized as recently as 1937. That cattle can utilize this form of nitrogen has been demonstrated since that time by various means: nitrogen balance experiments (Fingerling, 1937; Loosli and McCay, 1943; Lofgreen *et al.*, 1947); growth experiments (Bartlett and Cotton, 1938; Hart *et al.* and Work and Henke, 1939); milk-yield experiments (Owen *et al.*, Rupel *et al.*, and Archibald, 1943; Willett *et al.*, 1946; Ward *et al.*, 1955); body composition experiments (Loosli and McCay, 1943; Watson *et al.*, 1949), and tracer experiments with N^{15} (Watson *et al.*, 1949). As mentioned above, in vivo experiments with rumen fistulates also have demonstrated this phenomenon.

Significance of protein quality. In 1942 Miller and Morrison reported that the biological value of the protein in a wide variety of rations was 62, and during the same year Johnson *et al.* found similar biological values for the nitrogen provided by urea, soybean meal, and casein. Although these studies were conducted with sheep, they indicated that when nitrogen is provided at the same level it is utilized metabolically to the same extent by ruminants regardless of its source. As a consequence, there is no difference in the quality of protein feeds for mature cattle, as was demonstrated by Morrison and his associates during the 1930's. By 1956 the view that mature dairy cattle do not require pre-formed protein per se but rather require only nitrogen is gaining in strength. However, at the present time, there is not sufficient information on the requirements of the ruminal microorganisms to demonstrate this completely. In the early studies of the value of urea as a protein substitute, it was found that urea is utilized most effectively when simple carbohydrates such as starch and, to a lesser extent, sugars are in the diet and when there is very little or no highly soluble protein present. It was found that when urea provided from 40 to 70% of the nitrogen required by dairy calves 4 months of age or older, the rate of growth is 80 to 90% of that of heifers fed rations containing conventional nitrogenous sources. In long-time experiments milking cows have performed equally satisfactorily on rations to which urea has provided as much as 30% of the required nitrogen as on those containing the usual high-protein feeds. It is indicated that the quality of protein fed is of importance to young calves but not to animals whose ruminal flora is developed.

Elsewhere in this report is recorded a historical development of other synthetic functions of the rumen, particularly those concerning the B-complex vitamins and vitamin K.

Energy Metabolism Having Nutritional Significance

During the last 30 years of the nineteenth century much information on the metabolism of energy by cattle accumulated largely as the result of employing carbon-nitrogen balances in conjunction with respiration apparatus. Near the end of that century, Armsby introduced the animal calorimeter in which the production of heat by cattle could be measured directly and by use of which he evaluated feeds in terms of net energy. The attention given to the energy metabolism of cattle was most pronounced during the first three decades of the twentieth century. Notable contributions were made during this period, in approximately chronological order, by Atwater, Kellner, Armsby, Fries, Ritzman, Benedict, Forbes, Kriss, Mitchell, Brody, Swift, Kleiber, and Colovos, and their associates.

Gross Energy

Largely as a result of the efforts of Atwater (1899) and earlier workers, the gross energy values of common feedstuffs, though not greatly different, were found to be determined chiefly by the amounts of carbon, hydrogen, and oxygen contained in the feeds. However, after feed was ingested by the animal, the proportions of the original feed energy dissipated in the form of combustible gases, feces, urine, and heat were observed to be variable.

Energy Loss in Gases and Urine

Armsby in 1903 pointed out that the production of methane by cattle is related to the amount of digestible carbohydrates consumed, thereby tending to alienate methane production from crude fiber intake. Mitchell *et al.* in 1932 found the factor (0.045 g. methane per gram of digestible carbohydrate consumed) proposed by Armsby to be satisfactory. A refinement of this relationship in the form of an equation was proposed by Bratzler and Forbes in 1940 and verified further in 1943. The proportion of dietary gross energy lost as methane ranges generally from 5 to 12% and, as shown in 1917 by Armsby and in the 1930's by Forbes, Mitchell, and Brody, decreases as the level of intake

increases. They found also that the energy value of the urine usually does not exceed 5% of that of the ration consumed and that the urinary losses decrease with increasing levels of intake.

Loss of Matter and Energy in Feces

The major loss of dietary matter and energy is represented by the feces. In general, the energy value of the feces constitutes about 10 to 30% of the gross energy consumed as concentrates and 20 to 60% of that consumed as roughages.

Effect of level of intake. The loss of matter and/or energy in the feces of cattle consuming mixed rations or grain-containing roughages increases as the level of intake increases above that of maintenance (Eckles, 1911; Mumford, 1914; Trowbridge, 1915; Forbes, Mitchell, Watson, 1930's; Hale, 1940). However, the fecal loss from, or conversely the digestibility of, all-roughage rations was not found to be influenced by the level of intake (Watson *et al.*, 1935, and Hale *et al.*, 1940). In 1954, Blaxter and Graham fed dried grass at seven planes (five planes above maintenance) but observed no effect upon the digestibility of the energy.

Effect of stage of growth of forage. Although it has been recognized since the latter part of the nineteenth century that the digestibility of forages decreases as plants approach maturity and much additional qualitative information obtained from 1906 to 1956 supports that obtained earlier, it was not until 1952 that an attempt was made to quantitate the relationship between digestibility and the growth stage of forages at harvesting time (Homb, Jarl, Reid).

Effect of "associative feeding." In 1915, Ewing *et al.* suggested that the digestibility of certain combinations of feeds may be different from that expected on the basis of the digestibility of the individual feeds. This effect was termed "associative digestibility." Later work by Ewing (1915-1925), Watkins (1929), Forbes *et al.* (1931-1943), Watson *et al.* (1935-1939), and others shows that, although the effect is seldom greater than 5 percentage units of digestibility, it is sufficient to indicate that the digestibility of feedstuffs is not strictly additive in a ration. Watson *et al.* found no evidence of associative digestibility in rations comprised of various roughages and succulent feeds. But, the digestibility of feeds such as corn grain and silage, oat straw, and starch is improved noticeably when they are fed in combination with a feed of a higher protein content. Riddel *et al.* (1934) and Kleiber *et al.* (1936) found that a deficiency of phosphorus does not affect the digestibility of rations by cattle. In 1940, Mitchell *et al.* reported that the metabolizability of the energy in glucose is reduced because of an associative feeding effect involving glucose and the more complex carbohydrates in the ration.

Metabolizable and Net Energy

According to Armsby's concept, the dietary energy remaining after deducting the losses in the feces, urine, and gases is capable of transformation to useful products within the body and is termed metabolizable energy. Armsby recognized that the utilization of metabolizable energy results in a large and variable loss of energy in the form of heat. He compared the heat production of animals consuming a basal ration and that of animals consuming the same basal ration plus the feed in question and expressed the difference as the heat increment per unit weight of the test feed. Knowing that the measurement of net energy values for all of the common feedstuffs is a hopeless task, Armsby and Fries in 1916 developed factors which allowed them to derive metabolizable energy values from the quantity of digestible organic matter. From the metabolizable energy value, they deducted the heat increment for a given feed either measured directly or estimated from the value of a similar feed.

Effect of level of intake. From the very beginning of their studies at the Pennsylvania station in 1901, Armsby and coworkers noted the marked effect of plane of intake upon the magnitude of the energy losses in various forms, including heat, but from time to time Armsby's views on the importance of this problem varied and as recently as 1915 he did not believe that level of intake had much effect upon heat production. Among the last experiments planned by Armsby was a provision for testing his assumption that heat production is a rectilinear function of the level of intake. However, in 1927, Forbes, Armsby's successor, and Braman and Kriss pointed out that this relationship is not linear and, between 1928 and 1932, Forbes *et al.* and Mitchell *et al.* studied the problem intensely. These studies showed that the heat production curve is curvilinear at intakes below that maintaining energy equilibrium and approximately rectilinear above this level. As a consequence, the net availability of metabolizable energy over a wide range of intakes is not constant but decreases as the level of intake is raised. In 1932, Forbes and Kriss re-evaluated the heat production curve. It was pointed out that the hypothetical minimum heat production is less than that of fasting and that the curvilinear component of the heat production curve is attributable to the specific dynamic action of catabolized body substances and to chemical changes occurring in the metabolites. Therefore, the Pennsylvania workers concluded that fasting heat production does not represent the true maintenance requirement for net energy and that heat increment values of rations or feeds determined with respect to the heat production of fasting as the base value are fictitious and do not represent the true expense of energy in feed utilization. They proposed that the maintenance requirements of animals be represented by the quantities of feed

needed for approximate energy equilibrium. In 1940, Mitchell and Hamilton showed that the use of fasting heat production as a reference base may yield lower heat increment values, therefore a higher utilization of metabolizable energy, for less perfectly balanced rations than for more perfectly balanced rations. These views were supported further by Kriss in 1943. In 1944, Forbes and Swift showed that the summation of the specific dynamic effects for individual nutrients in a given feed is not necessarily equivalent to the heat increment of the feed and that the heat increment value of a ration does not necessarily represent the sum of those for the individual feed components.

Effect of dietary imbalances. Much of the work dealing with the evaluation of energy in feeds was done before the significance of vitamins, mineral elements, and amino acids was recognized. Before 1933, the Pennsylvania investigators had observed that the heat increment for a feed used in one ration could be much different from that for the same feed used in different ration combinations. Forbes *et al.* pointed out that, although the metabolizable energy values of some feeds may be high, they may be characterized by nutritive deficiencies which cause a large loss of energy as heat and, therefore, a low net energy value. These findings led Forbes in 1929 to state the view "that feedstuffs express their characteristic net energy values only as they are components of nutritively complete rations." Evidence was presented for an increased production of heat by cattle consuming rations deficient in protein (Mollgaard, 1929, and Forbes *et al.*, 1931-1933), phosphorus (Kleiber, 1936), and magnesium (Blaxter *et al.*, 1955).

Effect of purpose for which energy is used. In 1903, Armsby stated that the proportion of metabolizable energy that is utilized above the maintenance requirement to produce body gain is decidedly less than that used below maintenance to prevent the loss of body tissue. As a result of his study of Kellner's data, Armsby in 1917 suggested that the efficiency with which metabolizable energy is utilized, or conversely the amount of energy lost as heat, depends upon the purpose for which it is used. This was demonstrated experimentally by Fries *et al.* in 1924, Forbes *et al.* in 1926, and Mollgaard in 1929. The results of these studies indicated that the metabolizable energy provided to cows in excess of that required for energy equilibrium is used for milk production and body increase 98.5% and 76%, respectively, as efficiently as metabolizable energy is utilized for maintenance. In 1931, Forbes and Kriss reported that a constant relationship exists between the metabolizable energy of balanced rations (consumed above the level required for maintenance) and the energy value of the milk produced or of the body tissue gained. The net availability of the metabolizable energy in excess of the level maintaining energy equilibrium was found to be 69% and 58% for milk production and body increase, respectively. The failure to recognize the constancy of these relationships earlier appears to be the result of concentrating efforts mainly on the use of fasting heat production as the base line for the commencement of production metabolism rather than on that of the heat production at energy equilibrium (or maintenance). In 1934, Mitchell rationalized that the utilization of the metabolizable energy of balanced rations is maximal and equal for all rations balanced for the same species of animal and for the same body function. These views, already shared by Forbes and Kriss, made the measurement of the net energy values of individual feeds impracticable and unprofitable. However, this did not necessarily invalidate the net energy values proposed by Armsby for individual feedstuffs because in his manner of measurement the rations employed are generally well balanced and the level of intake was within the range of linear heat production. These concepts, formulated in the late 1920's and amplified in the 1930's, were still held to be valid by Kriss in 1943. In the early 1940's Axelsson argued that an optimum level of fiber for the maximum utilization of metabolizable energy exists. Although Breirem (1944, 1953) disputes this view, Blaxter and Graham in 1955 found a greater heat increment per unit of metabolizable energy with the ingestion of high-fiber grass (which may have been a poorly balanced diet) than with that of a lower fiber grass. However, by 1956, there seems to be no strong evidence contrary to the view set forth by Mitchell, Forbes, and Kriss. If the validity of this hypothesis can be definitely established it will mean that the net energy value of well balanced rations is proportional to the metabolizable energy value.

Basal Metabolism and Maintenance Expense

Much attention was given during the 1920's and 1930's to the basal energy metabolism (generally resting and fasting heat production) of cattle, particularly by Brody, Kleiber, Benedict and Ritzman, Mitchell, and Forbes. Although the basal metabolism of energy was found to be extremely labile, showing seasonal trends (even though determined in the range of thermal neutrality) and was greatly increased by the exposure of cattle to light and by activity, it was generally agreed then, and is held today, that the basal metabolism of energy increases, not directly proportionally with body weight but in proportion to about the 0.7 power of body weight. Brody showed that the maintenance energy expense is composed not only of the basal energy metabolism but also of an activity or muscular expense. From the standpoint of dairy cattle nutrition these early studies had their greatest significance in establishing that the need for energy in maintenance varies with the 0.7 power of

body weight which has been employed extensively in formulating maintenance feeding standards. Although a voluminous history of the energy metabolism studies with cattle in other connections exists, this brief sketch is intended to outline only that seeming to have most importance nutritionally.

ENERGY OR ENERGY-GIVING MATTER AND PROTEIN NEEDS

Maintenance

Energy needs. Among the most important developments of the last 50 years from the standpoint of economical feeding practice is the quantitation of the energy and protein needs for maintenance, milk production, and growth. As a result of the experiments of Armsby and Fries (1909-1922), Cochran *et al.* (1925), Forbes, Kriss *et al.* (1926-1931), Benedict and Ritzman (1927), and Mollgaard (1923-1929), the maintenance requirements of a 1,000-lb. cow are believed to be approximately 5.4 therms of net energy for fattening or 5 lb. of starch equivalent per day. The TDN requirements for maintenance (lb. per 1,000 lb. of body weight per day) were determined by various methods: 6.5, by live weight, Eckles (1913); 7.9, by live weight, Haecker (1914); 6.5, by live weight, Hills (1922); 6.0, by live weight, Forbes and Kriss (1931); 5.3, balance trial, Forbes and Kriss (1931); 6.7 by 2 × basal energy metabolism, Brody (1932); and 8.2 by algebraic partition, Brody and Procter (1935). Studies conducted by Armsby (1917), McCandlish and Gaessler (1920), Eckles *et al.* (1927), and Benedict and Ritzman (1927) demonstrated that the maintenance needs for animals in a high state of condition are greater than those for thin animals and that the maintenance requirement of animals fed at a low level of intake for a considerable period of time is reduced. Present-day feeding standards recommend an allowance of approximately 7.9 lb. of TDN to provide for activity and the reduced efficiency of feed use by milking cows consuming large amounts of feed as compared with that by dry cows fed smaller amounts of feed.

Protein needs. Studies of the protein needs for maintenance were carried out by most of the workers listed above as well as by Buschmann in 1923, Perkins in 1925, and Mollgaard in 1929. The requirement for a 1,000-lb. cow ranged generally from 0.53 to 0.70 lb. of digestible crude protein per day; most workers reported 0.6 lb., and this value is the one most commonly used in 1956. Also, the value employed today is essentially the same as that suggested by Henneberg and Stohmann as a result of their experiments with two steers almost 100 years ago.

Milk Production

Energy needs. Information on the energy needs for the production of milk was contributed mainly during the first three decades of the twentieth century. The requirements for the production of 1 lb. of fat-corrected milk in terms of therms of net energy for fattening according to various workers are: 0.21-0.29, Kellner (1912); 0.26, Armsby (1917); 0.28, Hansson (1926); 0.28, Mollgaard (1929); 0.28, Forbes and Kriss (1931); and 0.28, Halnan (1930). In terms of starch equivalent the requirement is about 0.25 lb. per pound of FCM. The requirement in terms of pounds of TDN per pound of FCM as derived from the energy studies of the workers listed above and as determined directly by Haecker in 1914 and Forbes and Kriss in 1931 and indirectly by Gaines in 1928 and Brody in 1935 ranges from 0.30 to 0.34 lb. The Morrison Feeding Standard (1948) suggests an allowance of 0.31 to 0.32 lb. with an additional allowance for pregnancy.

Protein needs. The knowledge of the protein requirements for milk production was contributed by many of the same workers who studied the energy needs of milking cows, as well as by Eckles (1913), Hills (1922), Hart *et al.* (1919-1922), Buschmann (1923), and Savage *et al.* (1932-1933). In most of these experiments it was found that when an amount of digestible crude protein equivalent to 125% of the total amount of protein in the milk is consumed above the amount of protein needed for maintenance, cows perform satisfactorily. Haecker (1914) recommended an allowance for production equivalent to about 175% of the protein content of the milk to provide a factor of safety. Morrison's standard records an allowance ranging from 125 to 150%. This provides from 0.041 to 0.049 lb. of digestible crude protein for the production of 1 lb. of FCM.

Growth

Growth standards. Among the various investigators there is less agreement on the protein and energy requirements for growth of dairy cattle than on those for maintenance and production by older animals. To some extent this is the result of the subjective criteria employed in establishing "normal" growth standards. During this semicentennial period numerous growth standards for dairy cattle have been proposed, among which are those of Eckles in 1920, Moulton in 1923, Ragsdale in 1930, Espe *et al.* in 1932, Moseley *et al.* in 1942, Bowling in 1943, and the Dairy Research Branch, USDA, in 1955. Although such standards are useful for a number of purposes, they infer that the rate of growth required to reach the "normal" size at a given age is that which is most compatible with productive performance and longevity. This may or may not be true as the productive-life performance of animals used to establish the growth standards has not been compared with that of animals reared at rates different from "normal."

Protein needs. In 1909 Popov found 6 kg. of protein stored in a new-born calf, and between 1907 and 1923 the slaughter-analysis experiments conducted mainly at the Missouri and Minnesota Experiment Stations focused attention on the great amount of protein stored in the body during the growth of cattle. In the meantime and for 30 years thereafter, by means of the growth, balance or factorial methods, the protein requirements for growth were determined by Armsby *et al. in* 1921, Forbes *et al.* in 1924, Swett and Eckles during the 1920's, Mitchell in 1929, Ritzman and Colovos in 1943, Blaxter and Price in 1946, Blaxter and Mitchell in 1948, and Lofgreen *et al.* in 1951. The requirements as determined by balance or growth experiments increase with size of animal, whereas those determined factorially decrease. The factorially determined protein allowances generally have been shown to be excessive for animals weighing less than 500 lb. and too low for those weighing more than 500 lb. when the Ragsdale growth standard is considered to represent the normal rate of growth. The National Research Council (1945 and 1950) and Morrison Feeding Standard (1948) recommendations are similar and suggest allowances ranging from about 0.4 to 1.0 lb. of digestible crude protein per day for growing animals weighing from 100 to 1,000 lb., respectively.

Energy needs. The allowances of energy for growth proposed by Kellner in 1913 were based upon studies conducted with only a few beef steers and those of Armsby in 1917 were based upon his treatment of the slaughter-analysis data reported by Soxhlet and the Missouri workers. Armsby assumed a uniform rate of gain from 1 to 18 months of age and he estimated that a pound of gain at 1 and 18 months represents 1.2 and 3 therms of energy, respectively. Factors for gain in energy were then added to his estimate of the maintenance energy requirement.

During the first 25 years of the twentieth century the results, particularly of slaughter experiments, emphasized that the proportion of the total growth requirement needed for the maintenance component increases with increasing body size and that the needs for growth alone depend upon the composition of the tissue and the rate at which it is gained. As a percentage of the energy of the total body, the energy required for the formation of new body tissue decreases with increasing age, but the amount of energy stored per unit of gain in body tissue increases with age because of a higher concentration of fat. The information provided by the studies of Eckles and Gullickson in 1931 and Ritzman and Colovos in 1943 contributed greatly to the data employed in working out present-day feeding standards. In general these standards provide allowances for about 2 to 11 lb. of TDN per day to animals ranging in weight from 100 to 1,000 lb., respectively. The factorial method suggested by Mitchell in 1929 for deriving the protein requirements has been employed by him to determine the TDN requirements (recorded in Maynard's *Animal Nutrition* in 1951) for heifers grown at the rate recommended by Espe *et al.* in 1932. These allowances are somewhat higher than those of Morrison (1948) for heifers smaller than 800 lb.

Is rapid growth compatible with optimum performance? The results of experiments conducted during the last 50 years with animals other than dairy cattle suggest that "normal" or rapid growth may not be as compatible with a long span of life as is slow growth. Although, during the 1920's and early 1930's, studies were made of the influence of level of feed intake during early life upon the productive performance of cows at the Kansas, Missouri, and Minnesota Experiment Stations, inconclusive results were obtained because of the small number of animals employed, and the experiments were too brief in duration to determine the effects upon longevity. Some of these studies suggested, as did that of Herman and Ragsdale in 1946, that extreme fatness in heifers is undesirable.

During the 1940's experiments were begun in Denmark, Sweden, and New Zealand and at the New York and Pennsylvania Experiment Stations in America with large numbers of animals to determine the effect of feeding level during early life upon lifetime performance. Although no final reports have been made, progress reports of the first 12 years' results of the Danish and Swedish experiments made in 1952 and 1956 suggest that levels of intake and rates of growth somewhat lower than those considered to be normal at the present time tend to prolong the life span of dairy cattle, whereas the consumption of large amounts of feed during the early growing period depresses lactation response and shortens the life span.

Fat Needs

Milking cows. After publication of Jordan's reports in 1897 and 1901 that milk fat can be produced from carbohydrates, the viewpoint developed that fat is merely a source of energy exchangeable on an isodynamic basis with other nutrients. As a consequence for some years thereafter very little attention was given to the fat content of the rations of cows. However, in Germany, Fingerling and his associates between 1904 and 1907 published data which, though showing that sheep and goats can make milk fat from carbohydrates, suggested that fat itself is more efficiently used than is carbohydrate. They also indicated that within certain limits the percentage of fat in milk is influenced by the amount of fat in the ration. These results provoked extensive studies with cows at ten experiment stations in Germany, which were reported by Kellner in 1907. However, since the low-fat rations used provided almost as much fat as was produced in the

milk, these experiments provided very inconclusive information. Practically no further attention was given to this problem until 1929. From that time until 1943, Cornell workers studied the importance of fat in the ration of dairy cattle. They found that when an isodynamic amount of fat is replaced by starch the milk yield declines. Although the effect is not great, slightly more milk was produced by cows consuming concentrate mixtures containing 5 to 7% of ether extract than by those consuming concentrates containing from 0.7 to 4%. These findings were verified by Huffman and coworkers during the 1930's, Leroy and Bonnet in 1947, Hansen-Larson in 1951, Dijkstra and Damміners in 1951, and Eskadal in 1953. When additions of fat as corn oil, soybean oil, or fatty acids were made to low-fat rations, the milk yield did not respond, suggesting that the value of the fat is depressed by extraction. Although most of these experiments demonstrated that the percentage of fat in the milk is not affected by varying levels of dietary fat in usual rations, high intakes of such high-fat feeds as soybeans, coconut meal, and palm kernel meal have produced at least temporary increases in the fat test. In some of these experiments it was found that the increased milk yield of cows receiving the high-fat rations is not the result of an increased intake of fat-soluble vitamins or of an improved digestibility of the ration. It is possible that the finding of Forbes *et al.* in 1946 that less energy is wasted as heat from equicalorie diets containing considerable fat than from those low in, or lacking, fat might explain the effect of dietary fat level upon milk yield by cows.

Young calves. Although Burr and Burr in 1929 and 1930 showed that certain fatty acids (linoleic, linolenic, and arachidonic) are essential for growth, skin health, and reproduction in rats, no special attention has been given to the needs of cattle for these fatty acids because the usual diet contains considerable amounts of them and cattle are known to tolerate diets very low in fat. In 1954, Cunningham and Loosli and Jacobson and his coworkers employed fat-free synthetic diets to demonstrate that calves within a few weeks after birth develop leg weakness, muscular irritability, and skin lesions, which could be cured or prevented by the addition to the diet of lard or the hydrogenated oils of coconut or soybean. Attempts to isolate from the rumen of cows microorganisms that are capable of synthesizing the essential fatty acids have met with failure.

Evaluation of Pastures

The nutritive value of pasture herbage in the form grazed by animals has been difficult to assay because of *(a)* the progressively changing chemical, physical, and botanical characteristics of forage which accompany growth, *(b)* the high water content of growing herbage, *(c)* the capacity of animals to graze selectively, and *(d)* the inadequacy of methods employed in the measurement of the nutritive qualities.

The value of pastures was determined prior to 1906 by a variety of methods, such as the dry matter or hay yield, the measurement of the clippings from representative plots before and after grazing, milk yield, and body weight gains. It was recognized during the early part of the twentieth century that these methods are prone to subjective influences and that they do not provide much information on the animal–plant grazing complex. The first major advance towards objectivity came during the 1930's when Knott, Hodgson, and coworkers proposed and used a method for the evaluation of pastures that has become known as the "reverse feeding standard" method. This was an attempt to equate the response in body weight and milk production and the maintenance needs of grazing cows to intake in terms of total digestible nutrients. Although this method assumed that the chemical composition of body tissue per unit gain or loss in body weight is constant and that the maintenance requirement of grazing cows is the same as that of stall-confined animals, it provided more valid information than did previously used methods.

In 1933, Garrigus introduced the dry matter consumption-excretion ratio method by the use of which he and others during the next 15 years evaluated pastures in terms of digestibility and dry matter intake. This procedure as modified by Forbes and Garrigus in 1948 involves conducting a hand-feeding trial with herbage clipped from the same pasture on which a grazing trial is conducted. The indigestibility of the forage determined in the hand-feeding trial in combination with the outgo of feces measured in the grazing trial provides an estimate of the dry matter intake. The validity of the results of this method depends largely upon the degree of similarity of the clipped forage used in the digestion trial and the herbage selected by the grazing animal.

After reports of the use of silica by Wildt in 1874, of chromium oxide by Edin in 1918, and of iron oxide by Bergeim in 1926 as reference substances for the measurement of digestibility, a search was made for substances occurring naturally in plants which might serve the same purpose. During the latter part of the nineteenth century a number of workers believed that lignin is indigestible whereas others found varying degrees of digestibility by employing methods that attempted to define lignin as a chemical entity. In 1938 Crampton and Maynard found that lignin might serve as a reference substance for measuring digestibility. Hale *et al.* in 1930 and Gray in 1947 employed lignin as a reference material for measuring the proportion of the total digestibility that occurs in the rumen. Despite much study between 1930 and 1945, the use of lignin as an indicator in hand-feeding trials was not very successful. After the introduction by Ellis *et al.*

in 1946 of a method for the isolation of lignin as an indigestible substance, the use of lignin as an indicator has been more consistently successful than it was previously. Using this procedure, Forbes and Garrigus between 1946 and 1953 made extensive studies of the digestibility of pastures. In addition to the technical difficulties involved in measuring lignin, its use as an indicator in pasture studies is limited by the uncertainty of manually sampling pasture herbage that accurately represents that selected by grazing animals. That selective grazing can cause large errors in the use of digestibility-indicator methods requiring the analysis of herbage was shown by Cornell workers in 1954. As the result of a study of 23 swards, these workers demonstrated that the average diet selected by grazing cattle contained 23% more of crude protein, 37% more of fat and 26% more of ash, but 17% less of crude fiber than the whole herbage cut from the same source. In addition the grazed herbage was considerably more digestible. In order to avoid the selective-grazing error, several fecal-indicator methods in which the analysis for the digestibility indicator is performed only on the feces have been proposed since 1949. These methods employ nitrogen (Lancaster, 1949; Raymond *et al.*, 1954), plant chromogens (Reid *et al.*, 1952), crude fiber (Raymond *et al.*, 1954), or methoxyl (Richards and Reid, 1952) as the indicator.

It has been obvious that the dry matter intake can be computed from the fecal output and the indigestibility of the consumed herbage. Although the output of feces by grazing animals can be measured by the use of fecal-collection bags, the possibility that this measurement might be effected by the use of inert reference substances administered to animals has been recognized since Edin in 1918 proposed the use of chromic oxide as an indicator in hand-feeding digestion trials. Although a number of substances have been proposed as "external" indicators, chromic oxide is the only one employed to any extent to measure the fecal output of grazing cows. Between 1950 and 1956 the dry matter intake of grazing cattle was derived by the use of chromic oxide as an indicator of fecal output and plant chromogens (Kane *et al.*, Hardison, Smith, Reid, and Meyer *et al.*) or nitrogen (Coup and Lancaster *et al.*) as an indicator of the indigestibility of grazed forage. The development of these methods employing the simultaneous use of a naturally occurring indicator for the measurement of indigestibility of grazed herbage and an external indicator for the estimation of fecal output affords the most objective means of evaluating the major nutritive qualities of pastures available by 1956. The revival of interest in the digestibility-indicator methods since the late 1940's has provided, in addition to their applications in pasture studies, means of conducting digestion trials with hand-fed feeds which are relatively inexpensive. This is made possible because, in the use of indicator methods, quantitative feeding and the total collection of feces are not required.

Feeding Standards

After 1906 the revision of feeding standards suggested earlier and the proposal of new ones provided for the feeding of dairy cattle on a basis much more scientific than that attained previously. In America, Savage (1912) modified Haecker's standard (1903), which employed digestible nutrients, chiefly by increasing the protein allowance by about 20%; Haecker also increased it somewhat in 1914. These were followed in 1915 by the standard of Henry and Morrison, which was called the "Modified Wolff-Lehmann Standards" and, in 1936, by that of Morrison. The latter standard set forth a range of allowances for dry matter, digestible protein, and total digestible nutrients. The twentieth edition of *Feeds and Feeding* was reprinted in 1937 with the addition of estimated net energy allowances. As additional information relating to the needs of dairy cattle (and other livestock) became available and as the economies of feeding practices warranted, the Morrison Feeding Standards were revised a number of times between 1937 and 1951. The standards published originally in the 1948 edition, of which there are several reprintings in use in 1956, set forth daily allowances for male and female cattle of various sizes and performing the various body functions in terms of total digestible nutrients, estimated net energy, digestible crude protein, calcium, phosphorus, carotene, and dry matter. In addition, a range of nutrient allowances and a scheme of monetary evaluation are recorded in the Morrison tables to provide flexibility for changing economic conditions. The wide acceptance of the Morrison Feeding Standards in North America attests to their great value. In 1945, and again in 1950, a National Research Council committee published a feeding standard for dairy cattle which also is based on the TDN system.

During the latter part of the nineteenth century information on the mutual replacement values of nutrients as energy sources was contributed by Voit, Pettenkofer, Zuntz, Meissl, Rubner, Kellner, and others. After these studies were reported, Kellner in 1905 applied the principles developed in formulating a feeding standard for dairy cattle. This standard and the starch equivalent system of feed evaluation on which it was based eventually became widely used in Great Britain and Europe. Kellner's standard was modified several times (1911, 1912, 1920) as dictated by new developments. Having first determined body-fat production values for relatively pure nutrients added to basal maintenance rations, Kellner then began to examine common feedingstuffs. The productive values of roughage feeds computed from

the factors he had previously derived from studies of pure, finely ground sources of nutrients were higher than those measured in concurrent respiration experiments. Kellner attributed the difference between the observed and expected values to the energy losses in mastication, ingestion, and fermentation, all of which, he felt, were related to the crude fiber content of the feed. Correction values were then developed to compute the starch equivalent value from the digestible nutrient content. Actually, correction factors were determined directly for only a few feeds. In formulating his feeding standard for milk production he compared the efficiency of energy utilization for milk production with that for fattening. Although Kellner computed a range of starch equivalents and digestible true protein for the production of low- and high-fat milk, he expressed his allowances for production and maintenance together as "milk yield per day per 500 kg. live weight," even in his latest (1920) standard.

In 1924, Wood in England proposed a feeding standard based on starch equivalents. Although he employed Armsby and Kellner's data as the basis, he assumed that 1 lb. of starch equivalent is equivalent to 1,000 calories of net energy. As a consequence, cows rationed according to this standard receive 5 to 10% more energy than those rationed according to Armsby's standard. Twelve editions of this standard, the last seven of which were prepared by Woodman, were issued through 1952 by the Ministry of Agriculture in Great Britain.

During the period from 1905 to 1921, Armsby, who had basic concepts similar to those of Kellner, developed a method of feed evaluation which has become known as the net energy system, and, in 1917, a feeding standard based thereon. Though the methods of both workers were based upon energy balance, their feed values were expressed differently. Kellner's method consisted of relating the fattening values of feedstuffs to that of starch and of expressing these values in terms of weights of starch, whereas Armsby deducted the heat increment value of a feed from the amount of its gross energy remaining after the deduction of the energy value of the feces, urine, and methane and expressed this as the net value of the feedstuff in terms of calories. Armsby felt that the loss of energy caused by the consumption of a feedstuff is determined by the difference between the animal's heat production on a basal ration and that on the same ration plus the feedstuff in question. Because of the impossibility of determining net energy values for all feedstuffs, Armsby and Fries in 1916 developed factors for computing metabolizable energy from digestible organic matter. Armsby then proposed that net energy could be derived by deducting from the computed metabolizable energy value the heat increment of the particular feed or of a similar feed. Since Armsby's directly measured net energy values applied to fattening, he made provisions for applying them to lactation. His studies of the data of Kellner (1911), Jordan *et al.* (1901), Haecker (1903-1914), and Eckles (1913) indicated that feed energy is utilized for milk production more efficiently than for fattening. As a consequence he computed the amount of energy for fattening that would be required to produce milk of various concentrations of fat. Recognizing that the digestibility of the ration is less at high levels than at low levels of intake as shown by Eckles in 1911, Armsby also made an additional allowance of 5% in formulating his feeding standard. This feeding standard set forth separate allowances for maintenance and the production of milk of various fat contents, in terms of net energy and digestible true protein.

Armsby's allowance for maintenance, though determined in calorimetric experiments with steers fed rations providing from submaintenance to supermaintenance allowances, was derived by a method based on the assumption that heat production varies linearly with the level of intake. This was later found to be erroneous. Also, it was assumed that maintenance and fattening are essentially equally efficient processes; however, in 1926, Armsby's successor, Forbes, and his associates showed that feed energy is more efficiently utilized for maintenance than for fattening. As a result of the development of certain principles (presented in the historical account of energy metabolism in this paper), Forbes and Kriss in 1931 devised a new method of application of the net energy concept to deriving the energy requirements for milk production in terms of both metabolizable energy and total digestible nutrients. Different allowances were provided for milk of various fat contents, and protein was expressed as digestible crude protein. Although it was never used much, this standard has more valid scientific bases than any of the previous energy standards proposed, and no findings reported by 1956 invalidate its bases.

Hansson between 1902 and 1926 and Mollgaard in 1929 proposed feeding standards based upon modifications of the net energy system in combination with the feed-unit system initiated by Fjord in 1872, which are employed in the Scandinavian countries. In 1915 the Danish, Swedish, and Norwegian feed control units agreed to adopt 1 kg. of barley as the standard unit of feed value. After Mollgaard's studies in 1929, Mollgaard, Frederiksen, and Breirem in 1935 introduced the feed unit for fattening that is equivalent to 1,650 net calories for fattening (NC_f).

Feed Input–Milk Output

During this semicentennial period much attention has been given to feed input–milk output (Ezekiel, 1927-1940; Frederiksen, 1931; Woodward, 1933; Headley, 1935; Cannon, 1940; Graves, 1940; Jensen, 1942; Yates,

1942; Hansen-Larson and Wenzel-Eskadal, 1951-1952; Hoglund, 1954, and their associates). Often, feeding standards are casually interpreted to represent the levels of nutrients required by cows to produce milk at their inherited maximum capacity. But, as the input-output experiments have demonstrated, increasing the amount of concentrates above the level needed to satisfy the nutrient allowances set forth in a feeding standard results in an increased yield of milk until the physical capacity or the maximum productive capacity of the cow is reached. When the price of milk is high relative to that of concentrates, it may be economical to feed cows a higher level of nutrients than that recommended in a feeding standard. These studies have demonstrated that an intake of TDN (total digestible nutrients) of about 25% in excess of the allowances of the commonly used standards increases milk production by about 15 to 20%. In addition, it was shown that the production response to increased amounts of feed is less at high levels of intake than at low levels. Therefore, the principle of "diminishing increments" operates in the conversion of feed to milk. The basic causes of diminishing returns are nutritional in nature because they concern the efficiency with which feed energy is utilized. When dry matter is the input unit, the diminishing output of milk per unit of feed, as input is increased, is the result of: *(a)* the decreasing TDN or energy value of the ration, *(b)* the increasing diversion of TDN or energy into body gain, and *(c)* the relative inefficiency with which energy is utilized for body gain. In some of the Scandinavian experiments, the extent of diminishing increments was not great. This appears to be the result of the feed input units used; because, when net energy is the feed input unit, there is no diminishing return. The input-output studies indicate that the level of intake at which cows begin to gain tissue is determined by heredity and that high-producing cows respond to high-quality roughages and pastures to a greater extent than low producers. An increase in intake of 1 lb. of concentrates reduces the intake of average-quality roughage by 0.5 to 0.7 lb. and of high-quality roughage by 0.4 to 0.5 lb.

The heart rate of cattle increases with increasing intakes of feed (Ritzman and Benedict, 1923-1924; Sykes *et al.* 1948; Thomas *et al.* 1951); for each 10% increment above the allowances of the feeding standard, the heart rate increases by about 8 beats per minute. The level of feed intake also affects the composition of milk. Before 1920 Eckles and Hart and Humphrey, and, during the 1940's, workers in Great Britain, found that the solids not fat and the fat contents as well as the total yield of milk decreased as a result of prolonged underfeeding. As a consequence of the experiments conducted on this problem, it is recognized in 1956 that feeding standards in combination with economic considerations provide an excellent guide to both scientific and profitable feeding.

SPECIAL PROBLEMS IN CALF NUTRITION AND FEEDING

Colostrum and Immunity

After Ehrlich's discovery in 1892 of the importance of colostrum in the immunization of mice, Famulener in 1912 found that goats also acquired immunity from the ingestion of colostrum. By this time it was recognized that colostrum is rich in globulin proteins and that the permeability of the intestines of newly born animals allowed the absorption of ingested antibodies.

The significant role of colostrum in the feeding of calves, however, was not determined until the experiments of Smith, Howe, Little, and Orcutt were conducted between 1920 and 1930. These studies showed that the blood of the newborn calf, different from that of the adult cow, contained no euglobulin or pseudoglobulin I, but that when colostrum was fed soon after birth these globulins appeared in the blood of the calf. When late-lactation milk or the post-partal milk of a cow milked prepartally was fed to calves, the amount of globulin in the blood of calves remained practically nil. The globulins absorbed from colostrum gradually disappeared from the blood of the calf during the first 4 weeks of life, stabilizing at this time at an approximately constant level for the remainder of life. In calves deprived of colostrum, the level of globulins gradually reached that of colostrum-fed calves in about 6 weeks.

The relation of these findings to immunity was also studied. It was found that even though the level of agglutinins for *Brucella abortus* in the blood and colostrum of the cow is high, the blood of her new-born calf was free from such antibodies until about 1 hour after the calf had ingested colostrum. These studies indicated a rapid absorption of antibodies into the blood of the calf. Many of the calves deprived of colostrum died, usually within about 1 week as a result of *B. coli* infection, whereas those having had access to colostrum survived. In other experiments it was found that the blood serum of the cow either ingested by, or injected into, the calf replaces colostrum effectively. The immunizing properties of colostrum were associated with the globulin fraction, which is absorbed as intact protein during the first 24 hours of the calf's life. The failure of the calf to contain antibodies at birth was attributed by Ratner *et al.* in 1927 to the large number of cell layers between the maternal and fetal circulation in the bovine.

It was not until 1942 that further studies of the protective effects of colostrum were made. At that time Jameson *et al.* confirmed the find-

ings of Theobald Smith and his associates and extended the earlier findings by electrophoretic methods. It was found that the serum of the new-born calf is devoid of γ-globulin but has a little of β-globulin, and that, following the ingestion of colostrum, γ-globulin appears and both forms of globulin increase during the first week of life. In more recent studies, Hansen and Phillips in 1947 reported that in colostrum-deprived calves γ-globulin increased as α-globulin decreased during the first 2 months of life and that in no case does γ-globulin increase when colostrum is given to the calf after the first 24 hours of life. An enzyme preparation from the gastric mucosa and chyme of a colostrum-fed calf partially prevented the increase in γ-globulin of the serum when fed to a new-born calf. In 1950, Laskowski and Laskowski discovered a tryptic inhibitor in colostrum which may explain the absorption from colostrum of intact globulin during the first day of life.

Between 1949 and 1956, Roy and his associates in England carried out extensive studies dealing with the role of colostrum in the rearing of calves. In addition to confirming many of the findings of earlier work, Roy observed that calves receiving antibodies from colostrum on the farm where they are born are not necessarily protected against colibacillosis when challenged by the microorganisms of a different environment. A diet containing 11.5% of non-fat solids of colostrum had a beneficial effect in reducing the incidence of scours and deaths caused by localized intestinal infections, even when the diet was administered after the time when the small intestine is no longer permeable to the transfer of intact globulins. When a high level of infection existed, a higher rate of mortality was found in calves fed synthetic milks than in those reared on whole milk, even though all calves originally had the same level of passive immunity. The postpartal secretion of cows milked prepartally was of less value than normal colostrum to the new-born calf. It was demonstrated that colostrum, but not normal whole milk, is estrogenic and that most of the activity derives from a conjugated form residing in the nonfat fraction of colostrum. Roy concluded that the nutritional values of colostrum for the young calf are equivalent to its immunological properties.

Esophageal Groove Function

That milk fed to calves passes directly to the abomasum was observed by Tiedemann and Gmelin in 1826. In 1928 Schalk and Amadon, employing gastric fistulae, observed the transport of ingested milk to the true stomach through a tube formed by the esophageal groove. They believed that when calves drank slowly the milk was conducted to the abomasum but that rapid drinking from a pail resulted in the passage of milk into the rumen, often with subsequent harmful effects upon the calf. The functioning of the groove in this way was found to diminish as the calf became older. Wester in 1930 reported extensive studies on the function of the esophageal groove, from which he concluded that the closure of the groove is caused by reflex action and that the presence of milk in the mouth of the calf stimulated the reflex because of the chemical nature of milk. In 1939 Wise and Anderson found that when water was suckled, it entered the abomasum; but that when it was drunk from a pail, most of it entered the reticulo-rumen. This proved that the chemical nature of milk is not a major factor controlling the closure of the groove. Schmoker in 1937 postulated that the position of the head and neck, being different in suckling than in drinking from an open bucket, influenced the closure of the groove. However, Wise *et al.* in 1942 showed that the position of the head during suckling and drinking was not a factor. In 1944 Watson suggested that the main factor determining the destination of fluid is the desire an animal has for milk or water at a particular time. He found also that mechanical stimulation of the buccal mucosa is sufficient to close the esophageal groove. In the 1950's Comline and Titchen studied the reflex action of the esophageal groove in decerebrate calves. It was found that copper solutions, which cause the closure of the groove in intact animals, were no more effective than water when administered to the decerebrate preparations.

Rumen Development

Lagerlof in 1929 made studies of the development of the stomachs of cattle from birth to maturity. He noted that the relative size of the stomach compartments was determined to some extent by the nature of the diet consumed, and he found that an increase in the size of the rumen relative to that of the other compartments resulted from the consumption of roughage rather than from that of concentrates. Extensive studies of the development of the stomachs were made during the 1950's by workers in New Zealand and by Warner at Cornell. Warner found that between 4 and 13 weeks the increase in reticulo-ruminal tissue relative to total body weight of calves fed dry feeds is about threefold, whereas practically no increase occurs in calves fed mineralized milk. The papillary development of the rumen wall was much greater for calves fed dry feeds than for those consuming milk. Nylon bristles did not stimulate papillary development, and the gross development of the abomasum was not affected by the diet. It appeared that the development of the rumen mucosa may be influenced by the chemical nature of the ingesta.

In an attempt to promote early rumen function and to encourage the utilization of high-

roughage rations, Pounden and Hibbs between 1948 and 1956 attempted to inoculate young calves with microorganisms from mature animals. Although these workers have reported such beneficial effects from "cud inoculation" as an improved appearance of calves and an increased digestibility of cellulose, other workers have reported variable results. In 1956 the benefits of this practice are unsettled; however, the extensive studies of the ruminal bacteria which are currently in progress give promise of clarification.

Calf Feeding Methods

Prior to 1920, feeds for young calves consisted mainly of whole or skimmilk fed either alone or with other concentrates, generally as a gruel. In 1924 Mead and coworkers at the New Jersey Experiment Station introduced a method that involved the feeding of a dry calf starter with a small amount of fluid whole milk. During the next 10 years and between 1933 (when Savage and Crawford developed the first Cornell dry starter) and the early 1940's, formulas for dry starters were greatly improved and the amount of whole milk fed was reduced to 350 lb. Generally the formulas were complex, resulting in considerable expense. During the 1950's Holter and Slack found that equally satisfactory dry starters could be made from very simple formulas. In addition, the Cornell workers found that, although calves fed as little as 150 lb. of whole milk are not as attractive in appearance during the first few weeks of life as calves fed 350 lb., the difference in size and appearance at 12 to 16 weeks is not noticeable. Between 1945 and 1950, highly satisfactory milk substitutes were developed for calves, particularly by Knodt, Loosli, and Jacobson and their associates.

In 1950, Loosli and Wallace, Bartley *et al.*, and Rusoff reported that the feeding of aureomycin effects an increased rate of growth in calves. As a result of the efforts of these workers and of Knodt, Jacobson, Warner, Riddell, and others, many aspects of the problem of antibiotic feeding have been examined during the past 6 years. In addition to the resultant growth response, the feeding of certain antibiotics has reduced the incidence of calfhood diseases and, in some cases, has stimulated appetite and improved the efficiency with which the diet is used. The antibiotics that produce these effects are aureomycin, terramycin, and streptomycin; bacitracin has not been studied extensively and penicillin has been detrimental. Thirty milligrams of antibiotic per day have been an effective dosage under most feeding conditions. The response to antibiotics is generally less under sanitary conditions and when milk is fed liberally than under conditions of slovenly management. Feeding antibiotics beyond 7 weeks of age has not been advantageous.

CONCLUSIONS

The knowledge of nutrition has expanded greatly during this semicentennial period. All of the known vitamins were discovered and the degree of their essentiality for dairy cattle was largely determined. The essentiality of magnesium, iron, copper, and cobalt was discovered, and important contributions were made to the already existing knowledge that calcium, phosphorus, iodine, sodium, potassium, and sulfur perform essential functions in the animal body. In addition, the toxic effects of substances such as fluorine, selenium, molybdenum, nitrates, and dicumarol occurring naturally in feedstuffs were discovered and, in some cases, means of prevention and/or cure were worked out. It developed that some of the mineral deficiencies and excesses prevailed in certain areas, implicating soil structure, climate, and fertilization and management treatments. Although an excellent foundation knowledge of the use of dietary energy by cattle had accumulated by the end of the nineteenth century, the greater part of the present knowledge derived from studies conducted during the first three decades of the present semicentennial period. Detailed studies were made of the biochemical, physiological, and pathological effects of dietary deficiencies, excesses, and interrelationships. The knowledge that the dairy cow by virtue of her rumen can digest crude feeds and synthesize many metabolically essential substances has largely developed during the last 50 years. The information thus accrued has been employed to determine the nutrient requirements of cattle for various body functions. Improvements in chemical methods used before 1906 and the introduction of new chemical, physical, and biological methods since 1906 have made it possible to describe more completely the nutritive qualities of feedstuffs, factors affecting these qualities, and the effects of the feedstuff upon the animal. Information resulting from these developments has been used during this period in conjunction with the knowledge obtained on the nutrient needs in the formulation of feeding standards and, therefore, in the practical rationing of dairy cattle. Although by 1956 there is much need to reinvestigate the needs of dairy cattle for certain nutrients, particularly in relation to nutrients discovered since some of the requirements were quantitated, present-day feeding standards in conjunction with economic values provide for the feeding of dairy cattle on a more satisfactory scientific and economic basis than ever before. Many problems seeming to implicate nutrition and feeding remain in 1956, however. An attempt has been made here to sketch the historical development of only a few significant occurrences in the nutrition and feeding of dairy cattle; the reader will recognize many gaps, as complete coverage has not been attempted.

Grassland Farming

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The importance of grass in livestock husbandry was recorded during Biblical times. There is also no question that grass played a vital part in the food economics of primitive man during the transition from the hunting stage to the pastoral stage of his development.

C. B. Bender

This transition was repeated time and again during the settlement of other continents. The settlers in our own continent followed the same pattern. They first satisfied their major animal protein needs with game of the forest and plains. This was followed by the growing of cereal grains and the gradual utilization of pasture lands for the livestock imported from across the sea. In the eastern part of our country, which originally was covered by forests, the vegetation consisted of grass, brush, and weeds after the cereal economy had depleted the soil of its natural fertility.

As farmers moved westward, they came to the prairie area with deep fertile soils covered with varieties of native grasses. They had more grass than they could use. These sods were broken up for the planting of grain crops as agriculture developed, and the rest of the area was eventually overgrazed. Plant nutrients were removed annually in the form of grain, beef, mutton, and milk, with no thought of replenishment. Overgrazing resulted in thin weak sods, with weeds and other plants of little or no feed value penetrating the area.

Intensively cultivated areas in all sections of the country, which caused rapid breakdown of organic matter, caused little concern until decreasing crop yields, gullies, and dust storms showed the necessity of making changes in agricultural practices.

Grass, without the livestock to consume and convert it into the high quality proteins found in milk and meat which are so essential to our optimum nutrition, would be of little immediate economic value. It has, however, many profound indirect values, which will be pointed out later.

Grassland farming, as it is known today, represents the integration of research on grassland crops within the fields of soils and soil fertility, agronomy, genetics, animal nutrition and production, economics, climatology, plant pathology, animal and plant physiology, chemistry and biochemistry, entomology, and engineering. Grassland farming, as a term for a system of farm management, only began to come into focus within the last 15 years.

FIG. 1. A well fertilized, mixed legume grass stand in a Grassland Program.

Factors Influencing Direction and Scope of Grassland Research

Within the last 50 years many forces affected agricultural research and practices. All of these had a tremendous impact and are not listed, necessarily, in the rank of their importance:

Exploitation and drainage of soil fertility resources.

A depression in the early part of the century, another about the time of World War I, the financial crash of 1929 and the early 30's, and the recession preceding the Korean conflict.

Two World Wars, the so-called Korean police action, and now the so-called armed truce.

The change from horses and mules as a source of power to gasoline, diesel oil, and electricity on the farm.

The increase of population from 80 million to 162 million while the farm population decreased about 30%.

Translocation of industry, tremendous increase in highways and housing, reduction in number of farms but increase in farm size, and increase in transportation facilities.

Doubling in number of all cattle and hogs.

Tremendous growth of the fertilizer and chemical industry.

Farm machinery revolution.

Irrigation.

Marked increase in farm land values, taxes, and labor costs.

Changes in land use.

Changes in systems of marketing agricultural products.

Effect on prices of supply and demand.

Fundamental Studies Which Showed Economic Importance of Grasses and Legumes

Much basic research had been done during this time on the feeding of ruminant and nonruminant livestock, which is so important to human nutritional well-being. This research, for the most part, will be listed under general categories because research workers in all parts of the country, in the federal service, and in industry have contributed to the studies which have made grassland farming possible.

Digestion and metabolism trials, which show that grassland nutrients vary in their composition and digestibility coefficients in the green state between varieties, at various stages of maturity, and with different methods of preservation.

The relation of soil type, fertility, and climate to the adaptability, longevity, production and nutritive value of grasses and legumes.

The study of root reserves in grasses and legumes and the factors of management which affect them.

The effect of lime and fertilization on the production, chemical composition, and nutritional value of grassland crops both for pasture and on harvested forage for winter feed.

The introduction and testing of new varieties of grasses and legumes from other countries and the selection and breeding of new, more productive, more palatable, and disease-, insect- and nematode-resistant strains.

The development of spray and dusting materials to reduce insect damage to legumes and grasses.

The effect of legumes and grasses in crop rotations, their stimulating effect on production, and the value of legumes in building a nitrogen reserve in the soil.

The economic value of pasture in livestock production and the realization that pasture is worthy of the most productive land on the farm.

Nutrient losses in hay-making due to overhandling, leaching, bleaching, and attempting to store it with too high a moisture content.

Methods of extending the grazing season through planting of summer annuals and grazing of winter and spring grains.

Rumen studies on the role of the microbial flora in synthesizing vitamins, amino acids, and fatty acids; in the digestion of complex carbohydrates; in the conversion of certain nitrogen compounds into amino acids; and in the occurrence of bloat.

Vitamin studies on green and cured roughages, their role in animal nutrition, and their retention under different systems of storage.

The role of grasses and legumes in building up organic matter content of the soil, increasing percolation of water, reducing and resisting erosion of soils, and retaining and building up soil and water reserves.

Feeding trials with ruminants to find the production potentials when excellent quality roughage was fed in the form of pasture, hay, and silage without grain supplements. These showed it was possible with the best roughage to get up to 82% of a cow's calculated production potential. With beef cattle on excellent well fertilized pasture, weight gains up to 3 lb. a day have been recorded in definite periods, and maximum gains on an acre basis up to one ton of beef per acre have been produced experimentally from a year's grazing.

Irrigation studies on the production of pasture and hay crops.

Grassland Farming Management Tools Developed by Research

In addition to this background work, several pieces of research and development in the period from 1927 to the present time brought grassland farming into true focus.

Rotation pasture fertilization and management and strip grazing.

Dehydration of hay.

Development of methods to preserve legumes and grasses as good-quality silage. This development had the greatest impact and could be called the cornerstone of the grassland program. The production systems were fairly well understood, but as long as hay harvest was complicated by adverse weather conditions grassland's true potentials could not be reached economically. Putting up grass silage overcame most of these hazards.

Development of the one-man baler, the pick-up and direct-cut forage harvester, ensilage blowers, self-unloading wagons and trucks, and the improvement in other farm machinery contributed greatly to the program.

Mow and batch drying of loose, baled, and chopped hay, with and without heat.

Zero grazing management.

Rotation Pasture Management

In the studies on rotation pasture fertilization and management where the pasture area was divided into 4, 6, or more areas and the total area was tailored to the size of the herd and productivity of the soil, certain principles were discovered:

When all of the pasture was of the same herbage composition, management to assure the cattle getting the highest quality pasture and adequate amounts during the season was quite difficult; in most cases, impossible.

Fertilizer was a tool of production, but the time of application, the ratio, and amounts for each pasture had to be varied.

On acid soils it was important to bring the pH within the range of 6.5.

Sixty pounds of nitrogen in the complete fertilizer or in addition to phosphorus and potash applied in the early spring advanced the grazing season about two weeks. Additional nitrogen applied early in June after a pasture had been grazed a second time usually extended grazing further into the summer and provided a quicker pick-up in fall.

In a six-plot system, manure could be applied in the fall or during the winter to two plots to stimulate growth if this first growth was removed for hay early in June. Aftermath grazing would be provided from the manured plots without refusal by the animals.

Heavy nitrogen and manural applications should be applied to different plots in succeeding years.

Management was improved and longer grazing was assured if each two plots were seeded to different legumes or legume-grass combinations, adapted to the soil type and maturing at different times.

Where summer drouths were the rule, hot weather annuals could be seeded to take up the summer slack and to renew a pasture seeding. Later the area could be disked or replowed and seeded to winter grain for some late fall grazing, overseeded in late winter with a new pasture seeding and the grain grazed down in the spring to reduce competition with the new seeding.

This system of grazing management increased the carrying capacity of a pasture and produced more milk. It also demonstrated the importance of management in the whole procedure. The weakest point was attempting to make good quality hay from the excess spring growth in early June. Later this was overcome by ensiling the surplus for summer or winter feeding.

In strip grazing, rotation grazing management was practiced but by means of movable electric fencing. A sufficient area of pasture was fenced off for one day's grazing for the herd, and the fence was moved daily to provide subsequent grazing.

Research on dehydration of hay proved that the principle was sound. It conserved the plant nutrients with a minimum of loss and did not destroy the carotene, and the drying operation could be conducted under weather conditions impossible for hay making. Costs of the hay were high, but when the hay was made into meal and fed with grain mixtures to poultry or hogs or in small amounts as part of beef, dry cow, and calf rations for its carotene and protein content, these costs were satisfactorily absorbed.

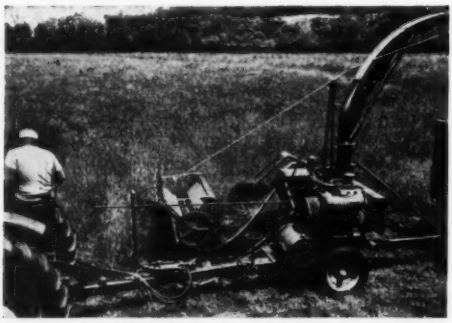

FIG. 2. Direct cut forage harvester—mowing, chopping, and blowing a mixed legume grass seeding into a trailer in grass silage operations.

Grass Silage—the Keystone of Grassland Farming for Quality Roughage

The development of methods of making grass silage of excellent quality through the use of adequate amounts of molasses or ground cereal grains as a feed additive preservative, or by wilting the grass to 65% moisture before ensiling it, or by the use of sodium metabisulfite as a chemical preservative proved to be the key to the Grassland Farming program.

With adequate storage facilities for silage, excess pasture could be cut and ensiled at the time for best pasture management and first cuttings of hay could be ensiled at the plants' best nutritive stage, practically without regard to weather conditions. By timeliness in these operations, second cuttings got off to a better start and could be made into hay when weather conditions were more favorable for hay making: a great improvement in farm management.

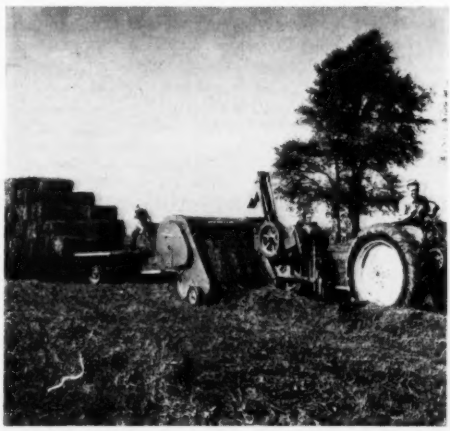

FIG. 3. Putting up second cutting alfalfa hay at the rate of 10-12 tons per hour.

Mechanization of a Grassland Program Speeds Operations and Reduces Unit Costs of Nutrients

Timeliness and speed are important in putting up roughage of high quality. The development of the one-man, string-tie, pick-up baler speeded up the haying process and reduced the labor required.

The forage harvester developed by industry was one of the most versatile machines for the grassland or roughage program. This machine cuts, chops, and blows green material into wagons, trailers, and trucks for transportation to the silo. Here, silo fillers meter the preservative and blow the material into the silo.

With a pick-up attachment replacing the mowing attachment on the harvester, partially wilted grass could be picked up from the swath in making wilted grass silage. This attachment could also be used for picking up windrowed field-cured hay and chopping it into trailers for barn or rick storage. By means of a corn attachment, this crop could be harvested for silage with the same equipment.

Self-unloading attachments were then developed for the wagons or trailers to further mechanize the silage operations. These machines eliminated the hard work from silage operations.

At about this same time a machine was developed to mow standing hay and crack the stems for more rapid drying. Research and practical

experience indicated a reduction in curing time of about 50%.

New Techniques in Hay Making

During the last 10 years, mow finishing of hay through the use of ducts and forced air was developed. Hay was cut and wilted to about 45% moisture, taken to the mow, and spread over the ducts, and the moisture was removed by air forced into the ducts and through the hay. However, when the humidity of the air was high, drying progressed very slowly. Other developments in the method have been to force heated air through the hay, and further changes have been made to batch- and wagon-drying of baled hay with forced hot air.

The costs of drying hay by these methods were much lower than by high temperature dehydration. This system of drying was found to be another economic tool in the Grassland Farming system in making high quality roughage for winter feeding of livestock.

FIG. 4. Delivering zero-grazed, chopped green forage to steers. No waste in the field or in the feedlot and labor is reduced to a minimum.

A Management System Which May Get the Greatest Production of Milk or Meat from an Acre of Grassland Crops

Zero grazing is the newest practice in pasture management. Essentially it is the soiling system of many years ago, but it is now a completely functional system because it is completely mechanized. In this system the cows are restrained in paddocks where they have shade, water, hayracks, and feed bunks. The forage harvester pulling either a self-feeding wagon or a power take-off driven, side-unloading forage wagon cuts and chops the green forage and delivers it to the cattle either once or twice a day. Under this system any forage crop may be cut and delivered to the cattle. The system is under research at many experimental stations and is being used on farms from coast to coast.

Listed advantages for this system are:

Elimination of practically all fencing.
No waste of green material through tramping and refusal.
No pollution of the land.
Greater utilization of the nutrients produced on an acre of land.
No selective grazing.
Greater consumption of green material.
Greater carrying capacity per acre of land.
More even production of milk.
Closer management control.
Lower production costs on well mechanized operations.

Grassland Farming Systems

Grassland farming can be carried on in many ways. It may be an extensive system where, under certain conditions of climate and topography, the animals may graze grasses and shrubs during the growing season and hay cured on the stem and other types of browse in the winter. In other sections of the country it is possible to graze green grasses and legumes for the entire season. In still other areas, where the grazing season extends for 5 to 8 months, the roughage program for winter feeding is extremely important.

Research has shown some of the things that can be done to increase the productivity of soils. Studies have been made of tillage practices, fertilizer placement, variety adaptability depending on soil and climate, methods of management of pasture, and grass silage and hay; industry has developed power and machinery to mechanize the programs. These studies must continue in order to secure greater production and increased efficiency in the years ahead.

With mechanization, more acreage and more livestock can be handled on the family farm with a decrease in labor and unit labor cost. A grassland program should be designed for the livestock carried on the farm to provide an abundance of pasture, grass silage and hay of the best quality available at all times to feed the animals at maximum intake. This lowers production costs. Even under the most extensive systems it has been shown to be poor economy to accept large losses in live weight during the winter when this could have been prevented by feeding supplemental hay produced on the ranch.

Year-round pasture is usually the cheapest way of producing milk and meat. However, possible drouth, unless land can be irrigated, must always be a calculated risk. A reserve of grass silage or hay or both in sufficient amounts to feed the herd for periods of months in some sections or years in others is the best kind of livestock insurance. Grass silage properly made and stored has been shown to lose little of its nutritive value even after years of storage.

A grassland farming program can be designed for the entire farm or for part of the farm. It can be tailored to crop rotations. It is extremely flexible. If necessary and the herd size remains constant, the grassland program may be expanded vertically by increased fertilizer use, thus freeing additional land for grain crop production. By utilizing the infor-

mation available today, milk and meat can be produced at the lowest unit cost with good, intelligent management.

Grassland farming management is both a science and an art. Poor management can deplete the soil of fertility and ruin it through erosion. With good management and by utilizing practices developed through research the soil can be enriched, the organic matter content built up, water holding capacity increased, the soil stabilized, more milk and meat produced, and thus a better living assured for the efficient farmer. It is not a static procedure; it's dynamic; it can change to meet changing conditions and to utilize new research findings. The management and design of the program must be planned and modified in certain respects to fit each particular farm.

Through well managed grassland farming practices it will be possible to provide the high quality forage so important to the nutrition and economy of livestock production. Furthermore, with improved practices, grassland farming will be able to supply the milk and meat to meet our growing population needs for many generations to come without competing with the cereal economy.

Infectious and Metabolic Diseases of Dairy Cattle

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Progress generally has its price, and for progress in the dairy industry during the past 50 years no exception has been made. Progress in transportation with its improved facilities in railroads, motor vehicles, and airplanes has made possible commercialization of the dairy industry by playing a dominant role in the movement of milk and its products to market and manufactured items back to the farm. At the same time, however, this progress in transportation, in permitting an ever-increasing movement of livestock and their products, has tremendously increased the ease with which infectious diseases of dairy cattle have been disseminated. During the same period, progress in breeding for greater milk production has been very successful. However, it has brought sharply into focus the need for concomitant progress in knowledge of dairy herd nutrition and management in order to avoid inadequacies as demonstrated by disease conditions like bloat or mastitis or metabolic problems such as parturient paresis or ketosis.

W. D. Pounden

Prevalent Diseases in the Early Period

Adoption of quarantine measures. The emphasis on disease problems as regards investigation and control has changed many times in the last 50 years, as would be expected. During the somewhat more than 20 years that the Bureau of Animal Industry existed prior to 1906, contagious bovine pleuropneumonia was among the first to demand serious attention and very fortunately was eradicated. Foot-and-mouth disease also was a problem prior to the organization of the American Dairy Science Association. Quarantine measures on an extensive scale had received adequate acceptance as valuable procedures in the control of animal diseases and expansion of their application had been inevitable. Curtailing the movement of diseased stock into this country or between states was an established procedure.

Tick fever. Another problem of major concern at the turn of the century was tick fever. It was of sufficient magnitude and interest that it materially helped stimulate the formation of the United States Livestock Sanitary Association just a very few years before the formation of the Dairy Science Association. This group stimulated action on disease problems and lent support to the work being carried on by federal and state officials, the American Veterinary Medical Association, and various other groups interested in the maintenance of a healthy livestock population. Although disease control as such was not considered a major field of interest among those organizing the A.D.S.A., it was not omitted. Through the efforts of its members and the leadership of its Health Committee much has been done to help solve disease problems and provide assistance in curbing the ravages of diseases among dairy cattle.

The same year that the A.D.S.A. was organized, the federal government started an extensive control program for tick fever. It was based on a program of systematic dipping of cattle. The progress made in control of the problem was so satisfactory that probably few of the present members of our Association have much recollection of what took place. This particular problem possibly was of more concern to owners of range cattle than to those of dairy stock; however, in many of the states during the first decade of this century it was a problem of importance to all owners of cattle. The research that led to the solving of this problem is of more than passing interest because it demonstrated for the first time an intriguing role that could be played by insect vectors in disseminating disease. This knowledge aided greatly in the solution of other disease problems, for example, malaria in humans.

Tuberculosis. Tuberculosis, a disease of major interest to the population of all countries, also was receiving considerable attention from veterinary and public health people during the earlier years of the present century. Considerable knowledge had accumulated concerning the pathology, etiology, character of the infection, methods of spread and diagnosis. In the live animal diagnosis was a rather laborious procedure involving subcutaneous injection of tuberculin coupled with the repeated recording of temperatures over a period of several hours.

Progress in the control of tuberculosis in dairy cattle was relatively slow during the 25-year period following the founding of A.D.S.A. In the meantime, diagnostic materials and procedures for the detection of infected stock were greatly improved and simplified. Included was the development of the method using intradermal injection of tuberculin that is the principal method used today. The extensive program that was designed to eliminate most of the tuberculous cattle in the country and thus to establish effective control of the disease was started in 1917 and was greatly implemented in 1934 during the period of drought and financial depression. This pro-

gram has been very effective and has reflected credit on everyone connected with its development and conduct. The value of the reduction that has followed in human cases associated with infection of bovine origin cannot be measured in dollars. However, the reduction in estimates of the incidence in cattle from almost 10% in 1906, to approximately 1.5% 25 years later, and to almost nothing at the present time indicates what it has meant to the livestock industry.

Reproductive Diseases

Brucellosis. Progress in raising milk production is dependent on adequate protection of the cow's reproductive function against disrupting agents. Far from being the least important of these diseases 50 years ago was brucellosis, which apparently had ravaged the cattle industries of Europe for centuries. The organism responsible had been cultured by Bang of Denmark and others in Europe during the last few years of the 19th century. However, this was not accomplished in the United States until 1910. Adequate credit and recognition could never be given the numerous investigators in federal, state, and other research institutions who have helped over the years to acquire the knowledge that has made possible the tremendous progress recorded in control of this problem.

The incrimination of *B. abortus,* as well as *B. melitensis,* as a pathogen for man has lent emphasis to the need for ridding the cattle population of this disease. It had been previously established that both organisms may be present in the milk of infected animals.

Control of the disease had to await development of suitable diagnostic procedures. What has since turned out to be an effective method is the agglutination test, which originated in Europe. First reports of its application to cattle in this country appeared in 1910. Both the original tube method and the plate method developed several years later have been extensively studied, improved, and widely used in control work. Another very valuable technique for use in detecting infected herds has been the milk ring test, which had its origin in central Europe before World War II but was not extensively used in the United States until recent years.

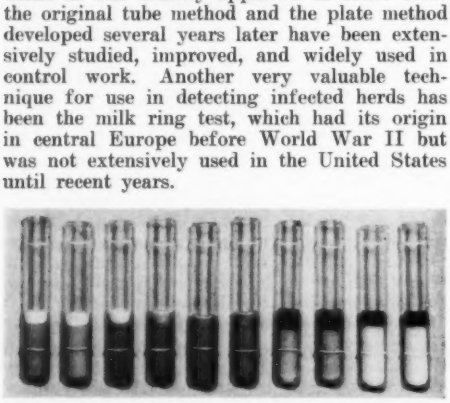

FIG. 1. The milk ring test. The stained brucella organisms rise with the cream in positive tests (right).

Development of a fully satisfactory method of immunization has not been accomplished. However, the protection afforded by mildly virulent living cultures when used in heifer calves approaching sexual maturity has been an outstanding development of research on this disease. Reports concerning studies with such vaccines in America first appeared in 1926, and shortly afterwards the now widely known Strain 19 organism was studied. The procedure was accepted with reticence for several years. In fact, it was not until 1941 that Strain 19 vaccine was released for general use. There were various reasons for this delay; resistance was incomplete and the blood serum agglutination reactions of vaccinates could not be differentiated from those of animals naturally infected with virulent organisms, thus presenting a control problem. Much diligent effort has been spent in attempts to develop more desirable vaccines, but so far none have proven as satisfactory.

Eradication programs, based on test and slaughter methods, were begun in 1934 and had variable success in some states. Much more progress has been made since World War II by using the same approach based on blood serum tests but supported by use of the milk ring test to facilitate early and speedy detection of infected herds. In addition, calfhood vaccination has been used in conjunction with the testing program to afford some resistance to infection. The net result has been that infection among cattle in the United States has been reduced from approximately 10% in 1934 to much less than half that (approximately 3%) at the present time, and some states are even discussing the possibility of complete eradication of this disease in the very near future. The disease still costs the livestock industry $45,000,000 annually, but this is less than half the estimated loss 10 years ago.

For this disease, as for some others, progress in control cannot be measured in terms of cattle, milk, or dollars alone; the effect on human health also must be considered. Here again, as in tuberculosis, reduction in incidence among cattle is being reflected in a similar trend in the human population.

The high morale in all groups concerned with curbing the brucellosis problem is evidence of the value of cooperation and the tremendous progress that can be made when people are working under a worth-while program in which compulsion is kept to a minimum. As pointed out in the *Journal of the American Veterinary Medical Association* in reference to the opposition encountered in the tuberculosis control program in 1931, "a law is only as strong as the public sentiment behind it." This reference to the progress made in organizing disease control programs so that all interested parties take an active part in their development and conduct perhaps is not out of place.

Trichomoniasis. Breeding problems are not limited to brucellosis. Although this disease may have clouded the picture for many years, the presence of other infectious agents eventually became apparent. One disease in particular was trichomoniasis, caused by the protozoan *Trichomonas fetus,* which had been recognized in Europe before the turn of the century as a cause of abortion or sterility. It is difficult to say when trichomoniasis first became a serious problem in North American dairy herds, but it seemed to be associated with the rising emphasis given to proven sires beginning about 30 years ago, which caused increased movement of older bulls between herds. Carriers of the infection left trails of sterility and other manifestations of abnormal breeding behavior in the herds in which they were used. Frequently the diagnosis had to be made without benefit of laboratory assistance and consequently often remained in doubt. The apparent widespread existence of the problem lent impetus to research which made possible improvements in culture media and more exacting methods for

FIG. 2. The mummified fetus is a manifestation of genital tract disease, e.g., trichomoniasis and leptospirosis.

identification of the organism. More correct diagnoses assisted in better control and treatment, and this progress began to make itself felt in the early nineteen-forties. Fortunately, artificial insemination techniques, although capable of spreading this disease if sufficient care is not taken, may also provide considerable assistance in limiting its spread. Thus, a valuable tool was provided for helping curb the ravages of this problem.

Vibriosis. One of the most erratically behaving infections of the genital tract is vibriosis. It is difficult to believe that it has not been present in this country in many dairy herds for some time, even though not recognized or given much attention until recent years. *Vibrio fetus,* the etiological agent, has been found in dairy cattle in many parts of the world and in most of the states. However, diagnoses confirmed by cultural methods had not been made in dairy cattle in some of the leading dairy cattle states until the period following World War II. Considerable progress has been made in fundamental research on this problem in recent years, but contradictory findings have been encountered. However, the development of diagnostic tests for infection along with more critical methods for differentiating the pathogen, such as the coagulase reaction, give promise that adequately efficient programs for control and possibly elimination of the problem are only a matter of time.

Leptospirosis. Another disease problem in dairy cattle that sometimes involves abortions among its manifestations is leptospirosis. Its presence in dairy cattle in this country had not been reported until some 12 years ago. Few dairymen had even heard the word 5 years ago, yet this disease is now listed as among those causing great financial losses in the industry. Fortunately, the progress made by the infection in spreading through herds is rapidly being matched by progress in understanding of the causative organisms and their *modus operandi.* Considerable advancement has been made in cultural methods for study of the organism and in the development of diagnostic techniques using serological methods. Much is known concerning the means by which the infection is spread and how control measures should be applied, and some treatments have shown promise of being successful.

Leptospirosis in the acute, systemic stages of the disease is accompanied by relatively high body temperatures. In this respect it is similar to some other disease conditions of cattle, including the shipping fever syndrome and some of the more recently recognized entities being referred to as mucosal diseases. Sometimes it is difficult to determine whether a disease agent is a new arrival or has been present all along but unrecognized.

Publicity concerning previously unheard-of disease entities may be disturbing to the livestock industry. However, the progress represented by the speedy recognition and description of new problems in recent years has been extremely gratifying. Furthermore, the follow-up in research necessary to develop control methods also has been good in spite of the pathetically limited budgets provided for this work.

Mastitis. It is only natural that the particular gland on a cow that secretes the product identified with her usefulness should also be associated with diseases causing the greatest financial loss. There has been no paucity of investigation of the problems of the udder, and the literature on the subject must exceed in volume all other disease conditions of cattle. Unfortunately, the extent of the literature is no indication of the extent of the progress made in coping with diseased udders. This is no reflection on those who have diligently studied the problems, because tremendous handicaps have been presented by the complexity of the physiology of the cow and her udder, the unending variety of microorganisms involved, and the multitude of variations encountered in en-

vironments. An unfortunate aspect is that too much of the progress that has been made during the lifetime of the A.D.S.A. in providing and applying basic information of value in controlling these disease problems has been partly nullified by excessive emphasis on differences in research observations. To a great extent the complexity of the problem as mentioned earlier has been responsible for this situation. Udder problems cannot be treated as a single disease any more than all abortions should be handled as if caused by brucellosis. Hope for the future lies in better appreciation of the reasons why differences in observations occur and the fact that no one phase of presently suggested control methods is capable alone of coping with all types of mastitic infections and manifestations of this disease complex.

It was little more than 20 years before the A.D.S.A. had its origin that streptococci were incriminated by French investigators. Since then, progress has been considerable in identification of various microorganisms associated with inflammatory reactions of udders, the number of different organisms now being legion and the list still growing. Furthermore, there has been outstanding progress in improving and simplifying bacteriological techniques and other procedures used for research and diagnostic purposes. As methods became available, such as the Hotis test and microscopic examination of slides, beginning about 20 years ago and followed later by more exacting identification methods like the Camp test, greater emphasis could be placed on segregation and elimination. Techniques for physically examining udders and for detecting changes in the secretions constitute additional methods that have provided a better understanding of the disease processes and have furnished help in developing control methods.

There has been a gradual recognition in the past couple of decades of the importance of satisfactory environments and proper milking procedures in avoiding mastitis. To a considerable extent the progress attained in control on both individual farms and through state-sponsored programs has been made by applying these details.

The evidence has been plentiful ever since the early years of the existence of the A.D.S.A. to show that the vast majority of mastitic infections enter via the teat canal. However, the means whereby this entry is accomplished have not been fully determined, even though progress is being made in this respect. The nature of resistance, or the lack of it, to udder infections and associated manifestations of disease is far from being adequately understood, but perhaps this can be bettered by future research. The complexity of the physiology of the udder presents problems in preventing disease conditions of this gland, but this very complexity seems to have its recompenses if one may judge by recent reports. Apparently, udders can be stimulated to produce and secrete in the milk the elements of passive immunity to some diseases and in this manner endow consumers with resistance to the diseases.

Progress in treatment of affected udders was slow for many years until the acridines and sulfa drugs were introduced in the late nineteen-thirties. Shortly after this, several other compounds were suggested as suitable for udder infusion treatments. Unfortunately, many were somewhat irritating to udder tissues. With World War II drawing to a close, limited quantities of the antibiotic, penicillin, were made available. It was soon apparent that penicillin was more effective than any of the other agents against *S. agalactiae*, the most prominent udder infection at that time, and in addition was not irritating to the udder. The development of penicillin and its marketing at a relatively low price have been in the nature of a major triumph in the war against *S. agalactiae*. Opinions differ as regards the amount of credit that should be given the antibiotics in the reduction of *S. agalactiae* infections, but none will deny that they have had a significant role in reducing losses caused by this organism.

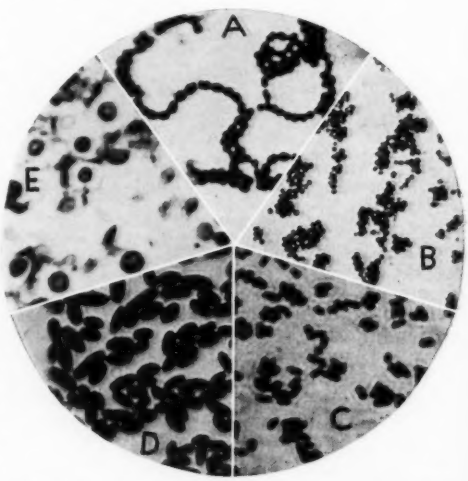

FIG. 3. Numerous organisms can produce mastitis; the few represented are: *(a)* streptococci, *(b)* staphylococci, *(c)* coliform, *(d)* yeast, *(e)* cryptococcus.

The antibiotics have proven to be of value in mastitic infections other than *S. agalactiae*, even though the results have not always been as favorable. Their application to these problems must be considered a marked advance when compared with previous results.

Antibiotics have proven helpful enough to encourage considerable reliance on them but,

unfortunately, have not been capable of controlling the problems alone, as some had hoped. The net result has been that sanitation and management control procedures have been excessively by-passed. It is possible that the industry would be further ahead in combating mastitis today if the antibiotics had not come on the scene until control procedures had been more universally adopted. There is a place for both types of approach, and progress is being made in bringing this to light.

Further Application of Antibiotics

Discussion of antibiotics brings up the tremendous progress that has been made in the treatment of many infections that plague dairy cattle because of the development of these and other modern additions to the veterinarian's armamentarium. Pneumonia, calf gastro-intestinal disorders, foot-rot, metritis, actinobacillosis, and conjunctivitis are just a few of the problems the seriousness of which has been curtailed through the use of antibiotics and chemotherapeutic agents. The risk of infection attendant under farm conditions on surgery involving such techniques as laparotomies also has been greatly minimized by the availability of these agents.

Developments in Professional Procedures

Surgical procedures themselves have been greatly improved in the past 50 years. More emphasis is placed on asepsis, far better instruments have been developed, and many new techniques have been evolved, even including such lowly details as castration and dehorning with Burdizzo forceps and electric dehorners. Caesarean section, surgical repair of hernias, rumenotomies, rumen samplings and lavages, and nerve blocks for anesthetic purposes, such as the epidural and paravertebral methods, are among the many procedures that have reached such stages of development in recent years that their use is profitable and they are undertaken without hesitation.

Immunological procedures as means for coping with animal diseases were receiving much attention during the period around the turn of the century when some outstanding progress was made; for example, development of immunizing agents for blackleg and the serum and virus treatment for the prevention of hog cholera. Although progress through immunology in general has kept up with other betterments in livestock disease control, it is doubtful if it has been proportionately as great in regard to American dairy cattle. Nevertheless, immunizing agents for two of the worst cattle scourges in the world, namely, rinderpest and foot-and-mouth disease, were developed and Strain 19 vaccine was made available for assisting in the control of brucellosis.

FIG. 4. Abdominal surgery is now commonplace.

The application of immunology to diagnostic procedures has been a fertile field of endeavor, and progress has been gratifying. Serological identification of infected stock, as is done by using agglutination tests for brucellosis, or complement-fixation tests for anaplasmosis and the identification of strains of virus infections are examples that come to mind. Much progress also has been made in developing means for accomplishing differential diagnoses by using the knowledge obtained in various branches of science, such as microbiology, chemistry, physics, and radiology. Furthermore, a vastly better understanding of almost every cattle disease problem has gradually been obtained through physiological and gross and histopathological studies. It represents considerable progress and the value of this knowledge is frequently demonstrated when the causes of problems having similarities have to be determined. Do the patient's high temperature and hemorrhages mean anthrax or bracken poisoning? Do the oral lesions mean an outbreak of foot-and-mouth disease or merely vesicular stomatitis? The wobbly gait and general distress, are they accompanying a case of ketosis, rumen dysfunction, or exposure to a toxic substance? Questions like these can be and are being answered with increasingly greater ease.

Some Adverse Results of Progress

Progress within the industry may bring problems elsewhere. Some dairy cattle health problems appear to be in the category of being instigated through progress in other fields. Parturient paresis, or milk fever, is believed to have been almost nonexistent a century or more ago and prior to the time when considerable progress was made in the quality of dairy cows and their diets. Somewhat similar suspicions have been directed toward ketosis.

Milk fever. The status of the knowledge 50 years ago indicated that tremendous progress had been made in the years just preceding. Less than 10 years before this time, Schmidt had not published his epoch-making discovery involving mammary infusion of a disinfectant solution, and no satisfactory cure or prevention was available. Yet by the time the A.D.S.A. got under way, the technique and special equipment for udder inflation with air were being

used extensively and mortality was being reduced remarkably. Significant progress on the problem next occurred in the late twenties and early thirties when several fundamental studies were undertaken. These investigations showed the relationship between the symptoms and hypocalcemia and resulted in the development of the rational procedure of injecting calcium salts, the present-day treatment of choice.

Little progress was made in preventing milk fever until rather recently when two methods were suggested that give promise of being of value. One consists of withholding calcium from the diet during the weeks just prior to freshening in order to assist in maintaining the calcium mobilizing mechanisms in a satisfactory state. The other involves feeding massive doses of vitamin D during the week prior to freshening for the purpose of stimulating blood calcium levels so that they will be sufficiently high to avoid attacks.

The advances made in studies of the fundamentals involved in milk fever have furthered progress in other metabolic disturbances, particularly the syndrome known as grass tetany. In fact, investigators who were active in the earlier work involving blood mineral levels in milk fever were responsible for much of the progress made in determining the relationships of the same things in grass tetany.

Ketosis. Diagnoses of ketosis and acetonemia are a relatively modern innovation and were not in the books 50 years ago, but the clinical syndromes may have existed long before that and been noted under a number of different names and with various explanations. Back about the time the A.D.S.A. had its origin a condition closely resembling ketosis, if not ketosis, was being diagnosed by some veterinarians, particularly in the British Isles. "Palsy after calving," "retention of the second cleansing," and "acidosis" were other names used over the years for debilitating conditions causing serious loss in production just when fresh cows were expected to do their best. The problem received increasing attention in central Europe beginning in the nineteen-twenties and shortly thereafter in this country. The emphasis placed on blood chemistry in these studies helped greatly to demonstrate the metabolic nature of the problem and to quite an extent led to the development of rational means for alleviating the condition. Although the final word has not been written on the basic causes of the breakdowns in the health of the animals, progress has been relatively good in this respect, and in addition improvements have been made in diagnosis and treatment. Progress through extensive diagnosis of the problem in the United States followed use of the simplified urine test. Injection of glucose solution reported in Europe in 1926 as being helpful has proven to be a treatment of great value.

Fundamental and observational studies have brought to light the probable relationship of the syndrome to inadequate rumen function and factors which place the animal under excessive stress. Recognition of the latter has provided a further advance in treatment, the administration of cortisone and similar hormonal products. Progress in better understanding of ruminant digestion and metabolism has suggested treatments and preventive measures with products similar to those that are formed during normal rumen digestive processes.

Bloat. From a practical standpoint bloat also may be placed in the category with health problems that have become of more serious consequence through progress in feeding programs because of the close association it frequently has with certain of the better forage crops. It can hardly be said that great progress has been made in the control of this problem even though the condition and its unfortunate results have been known for centuries. A physically practical, but profit-wise impractical, control procedure is to limit the diet to forages that do not cause it. However, progress over the years in making use of management procedures has been moderately good, and progress also has been made in obtaining a better understanding of the fundamentals involved.

FIG. 5. Rumen contents: frothy bloat (left) and normal (right).

As with the investigation of many problems, progress is often closely tied in with the development of methods for use in the research studies. The technique for making permanent rumen fistulas, developed some 30 years ago, is an example. It has served usefully in shedding light into the dark chamber of the rumen under conditions of both health and disease. Considerable knowledge of value in unraveling malfunction of the ruminant digestive tract has been accumulated. It relates to rumeno-reticular movements and atony, the physical properties of the contents, microbial inhabitants and their metabolic and catabolic activities, and absorption mechanisms of the organ. Thus, there is every prospect that much of the fundamental knowledge concerning rumen dysfunction still desired in such fields as physiology, bacteriology, and biochemistry will be provided before too long. Progress has been made also in treatment of malfunction of this part of the bovine stomach, for example, rumen lavage for removal of undesirable contents, as popularized during the early nineteen-thirties, and in more recent times the use of defoaming agents in some kinds of bloat.

Deficiencies and Excesses

Mineral and vitamin deficiency diseases. Although cattle through rumen function are blessed with abilities to maintain a healthy status on diets physically and chemically unsatisfactory for other stock, they still have their limits. The progress made in determining the needs in minerals and vitamins and their provision for the maintenance of health has been one of the most engrossing stories of recent decades. Pica and conditions of wasting away associated with phosphorus and cobalt deficiencies and goitre of calves due to lack of iodine, each a problem that seriously plagued the cattle in various locations, are now seldom observed since the causes were determined and the course of prevention provided. Similar circumstances have surrounded the progress made in vitamin studies. Through the knowledge accumulated by the intensive energies of innumerable scientists it has been possible to greatly limit the early deaths, blindness, and other unhealthy conditions associated with vitamin A deficiencies. The same is true of the crooked legs and stiff legs that accompany the lack of vitamins D and E, respectively.

Sweet clover poisoning. The solving of sweet clover poisoning is an example of progress in the sphere of the opposite of deficiencies, namely excesses. First came the keen clinical observations made several decades past that connected the mouldy condition of the plant with the hemorrhages in animals eating the hay. Then came the chemical conquest that was accomplished little more than a decade ago in determining the active agent. Still further progress later changed the killer to a cure for human ills and an eliminator of undesirable rodents. Truly a saga of progress. Clinical and chemical prowess have teamed together in the past half-century on a number of occasions to help solve cattle poisonings caused by substances in plants. Many accomplishments have been achieved, for example, an understanding of the role played by excessive consumption of selenium and nitrates.

Illnesses traceable to foodstuffs. Progress and improvements in methods of manufacturing and processing materials and feedstuffs have had some unfortunate effects upon livestock health. Two that come to mind are the use of chlorinated naphthalines in lubricants and wood preservatives and the trichlorethylene method for extracting oil from soybeans. The severe losses that resulted from hyperkeratosis associated with the former and the deaths that followed use of the latter are well known to the livestock industry. The research that went into the solution of hyperkeratosis was outstanding. It demonstrated a progressive approach involving cooperation and coordination of the efforts of the staffs of several experiment stations and the Animal Disease and Parasite Research Branch of the Agricultural Research Service.

Tremendous progress has been made in the development of better insecticides, herbicides, fungicides, and dozens of similar types of products, but here again there has resulted some small risk to cattle health. By and large, these have been very limited because of the care taken by the manufacturers and others to provide educational programs so as to avoid as much as possible the incorrect use of dangerous materials. These steps in themselves constitute a progressive approach, which is gratifying to observe.

Progress in the Control of Parasites

Fifty years ago it frequently was a losing fight against animal parasites, but thanks to the progress made in chemical industries much can be accomplished today. The development before World War II of phenothiazine and its extensive application in recent years for the control of internal parasites is an excellent example of the progress that has been made in this field. In the control of flies and external parasites just as much progress has been made. Not one product but several chemicals are now available and are widely used for this purpose. No doubt, better drugs are on their way and better methods, too. Suggestions of what the future holds include the possibility that inject-

FIG. 6. Mass of tapeworms in the intestines of a calf. Efficient treatments are now available for internal parasites.

ing animals or feeding them chemicals will provide a means for eliminating the ectoparasites that pester them and pilfer profits.

It would be incorrect to leave an impression that all the progress in parasite control had been made in the development of chemicals lethal to these organisms. Much intensive and very productive research has been directed towards unraveling the life cycles of bovine parasites, their intermediate hosts, the means whereby they produce the pathological conditions, and the means that offer help in control. Furthermore, the progress made in applying extensive programs for control of such problems as scabies should not be overlooked, for prevention of losses is comparable to "the penny saved." Future progress in these fields looks very promising.

FIG. 7. Poisoned by an insecticide containing arsenic.

Much Remains to Be Done

Surely the accomplishments, disease-wise, have been tremendous in the 50-year lifetime of the American Dairy Science Association. The steps from toleration to eradication of bovine tuberculosis and from setons and sulfur to sulfas, antibiotics, and vitamins are a couple of examples indicative of the brightness of the future. However, it would perhaps be wise to review the tremendous challenge that still remains. Annual loss in the dairy industry from disease has been estimated to equal the profits. The figures resemble those in the United States defense budget, for instance, mastitis, $250 million; brucellosis, $45 million; and a single parasite, the cattle grub, estimated to cause single-handed a loss of $100 million. Although much of the loss could be avoided by proper application of available knowledge, very much more will be possible as research produces the facts necessary for developing control methods.

Development of Dairy Farm Engineering

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Progress in dairy farming was well under way at the beginning of the 50-year period, 1906 to 1956. Scientific achievements and discoveries of the two or three decades preceding the date on which the American Dairy Science Association was founded brought into use the butterfat test for milk, the cream separator, improved forages, improved feeding practices for dairy cattle, herd health protection by the tuberculin test, improved sanitation, dairy cattle breeding for the improvement of production, pasteurization of milk, and a proven evaluation of milk and butter as a superior source of human food. The milking machine and stainless steel had been invented but their use was to come later.

S. A. Witzel

The Dairy Farm of 50 Years Ago

The dairy barn was also in for its fair share of attention. The discovery of tuberculosis in dairy herds and pathogenic organisms in milk which were causing epidemics and deaths in humans had focused attention on dark, filthy, poorly ventilated stables for dairy cows and this, in turn, had brought forth a crusade for improvement. Scientists at agricultural experiment stations had been perfecting silos, barns, ventilation systems and power applications. The agricultural press was then, and has continued to be, most helpful in bringing new information to the dairy farmer. Dairy farm equipment manufacturers were supplying equipment and helpful planning assistance as they have continued to do throughout this period. The new dairy barn being built by the well informed dairyman in the early nineteen-hundreds was a two-story building with a large storage space on the second floor for hay and bedding, and it often had a threshing floor and grain bins. This haymow could be filled by a track with carrier and fork. A round silo had taken its place at the side or end of the barn.

The economic advantage of larger herds had led to the construction of numerous large dairy barns, which were widely publicized. In some of the newer barns the first floor had two rows of cows and either a driveway or litter carrier. The cow stalls in these barns were generally equipped with concrete floors, mangers, gutters, and swinging stanchions, and some had individual water bowls. Although the short cow stall with moderately deep gutter was considered best for keeping the cows clean, the comfort stall was being promoted by some dairy leaders. Wood overlays in the stalls and deep bedding also were used to make the cows more comfortable. Some daily outdoor exercise was considered essential in good herd management.

A barn ventilation system had been developed to meet the need for better herd health and sanitation. Research workers reported increased milk production in warm, ventilated barns based on increased milk weight and decreased feed consumption. Weight losses of cows in warmer barns were found and reported in these studies, but the test periods had been too short to allow the cows time for acclimatization or for the weight changes to take on important meaning. Dairymen were advised to provide a well ventilated, moderately warm, stall-type, two-story barn. Once established, this trend continued well into the 20th century until almost every dairy herd in the Midwest and Eastern United States was so housed. Except for some remodeling, a large percentage of the dairy barns in this area still remain as they were built 30 to 50 years ago. In other areas, adaptations of the stall barn to fit local needs were used.

Evolution in Use of Mechanical Power

Power on dairy farms consisted mainly of muscle and brawn supplied by man and beast. However, limited help was already coming from the application of mechanical power. Wind power was pumping the water into elevated storage tanks for gravity distribution to house and barn. Steam engines were threshing the grain and chopping the silage faster than could the limited power from treadmills or sweep horsepower machines. The internal combustion engine had been fully developed and was beginning to appear on the market. Electricity had just entered the farm market. Both of these latter sources of power were destined to become major sources on the dairy farms of the United States within the next 50 years.

The American farmer had won relief from many grueling tasks in the late 19th century through the use of horse- and mule-propelled field machinery. This equipment included riding machines for plowing, tillage, seeding, cultivating, hay making, and harvesting. The effect of this mechanization of agriculture was shown in the shift of the percentage of total population living on farms, which was 77.5% in 1840 and 35.1% in 1900.

Increase in Productiveness of Farm Labor

With the foregoing account of the rapidly moving cavalcade of progress in agriculture and dairying as a "point of beginning" the record of progress of the next 50 years takes on new meaning. Aided by scientific and technological advancements, agriculture as a whole has continued to show steady improvement in terms of total output and in most field crops per agricultural worker. To fully appreciate the amount of this great increase in production it is noted that the population of the nation has increased over 100%, while vast exports of food have been made and large surpluses have accumulated. During this period the percentage of the total population living on farms dropped to less than 14%. However, 40% of all employed Americans are presently connected with agriculture, 16% on farms, 10% to provide service to farmers, and about 14% to process and distribute farm products.

Progress in dairy farm engineering has been discouragingly slow compared to engineering advancements in farm crop production, as show below.

Index numbers of man-hours per acre
(From USDA *Tech. Bull.* 1020)

Item	1910-14	1950-53
Wheat	100	29
Corn	100	37
Hay	100	55
Cotton	100	60
Milk cows	100	85.6
Man-hours per milk cow	146	125 (1950)

During the first two-thirds of this period the increased care given cows to obtain better production and produce a higher percentage of whole milk for sale and the extra time required to meet advanced sanitary standards nearly canceled out all labor-saving advantages that had accrued from the use of milking machines, more modern barns, and other improvements. However, during World War II a new movement of herd consolidation and greater mechanization has resulted in some improvement in dairy cow labor efficiency. There was evidence that, as a group, dairy farmers had been slow to make improvements that would increase labor efficiency. This was indicated by the fact that in 1950 only 51% of the cows were machine milked and the average number of cows per herd was six. In herds that were machine milked the man-hour requirement per cow was 111 and in herds milked by hand the requirement was 140. It would be expected that the larger, better equipped dairy farms would be represented in the group having milking machines. This, no doubt, reflects the benefits of some of the improvements brought about by advancements in dairy farm engineering.

The slow rate of improvement in dairy farm engineering as indicated by the man-hours per cow data has a somewhat brighter side when the increased production per cow is considered. It is true that there is considerable overlapping in the fields of dairy farm engineering and dairy science, as well as in others such as the agronomy and soils groups. The over-all effort of the workers in these fields has contributed to the numerous advances which have tended to increase the production and marketings of milk per cow. This trend has been more pronounced in some areas than in others, thus indicating opportunity for further improvements which would affect national averages. In 1906 it required, on a national average, approximately 3.4 man-hours to produce 100 lb. of milk. In 1950 it took 2.4 man-hours. However, in five states this average was 1.7 man-hours or less per 100 lb. of milk, and in one state, which had the highest milk production per cow, the figure was 1.5. Another interesting observation is that in regional areas having the highest production per cow, where the time for care of the cow and the milk she produces would tend to be the highest, the labor requirement per unit of product was the lowest.

Dairy farm engineers feel that much remains to be accomplished in raising dairy cow labor efficiency. To do this will take money, hard work, time, and the full cooperation from several groups—administrators of research funds; the scientists in related fields; industry; and the dairy farmers themselves. Research involving buildings, herds of dairy cattle, and dairy farm equipment is very costly and time-consuming. Carrying these results to the dairy farm and translating them into actual practice is also a continuing responsibility of dairy farm engineers as well as the cooperating workers in the related dairy sciences.

Important Mechanical Advances

Since this paper deals, insofar as possible, with the engineering phases of dairy farming, it is interesting to note that the American Society of Agricultural Enigneers was founded in 1907. The activities, meetings, and published papers of this Society have contributed much to the advancement of dairy farm engineering as with other engineering phases of agriculture.

The first successful application of the internal combustion engine to the farm traction machine came in 1908, and the adaptation of this machine to rubber tires in the thirties had a far-reaching effect on dairy farm operation. In addition to providing more power and easier operating conditions in the fields, it served as an important aid in doing chores about the farmstead. Finally, owing to tractors and farm trucks on the farms, the nation's horse population on farms dropped from 23 million in 1917 to 5 million in 1953. This

released roughages, pasture, grain, and shelter for use on dairy farms. Tractors, new machines, and large tractor-operated equipment reduced field time. Thus, more feed could be raised to support more cows.

The appearance of the hand-operated cream separator on the American market before the start of this century and the first national public exhibition of the milking machine in daily operation at the National Dairy Show held in the Coliseum at Chicago in February of 1906 created a need for power on the dairy farm that could not be supplied by the windmill or treadmill. Thus, the stationary internal combustion engine came into widespread use. It was often belted to a lineshaft from which the vacuum pump, water pump, cream separator, and churn were operated. Later these engines were connected to electric generators for "lighting" on the farmstead.

Another power source was destined to replace the internal combustion engine before mid-century. This was the application of central station electric service to the farms of America; in 1954, 93% were connected. With electricity came the convenient electric motor, good lighting, and the pressure water system. Other uses include mechanical ventilation, feed handling, manure removal, milk line cleaning, milk pumping, heating for water and space, refrigeration for milk, and many other uses which greatly lessened the drudgery of the dairy farm. Electricity on the farm also added better living for the dairy farmer and his family.

The Role of Engineering in Feed Production

Better feeds and roughages were a contribution to more efficient dairying in this period. The development of supplemental drying for conditioning roughages and grain after harvest, with the use of forced air and heat as needed, resulted in preventing heavy losses in nutrients, vitamins, and palatability. New harvesting equipment such as field balers and choppers, the latter adaptable to both grass and corn harvesting, were developed. When the chopper was used with self-unloading wagons, the operation of getting the crop into storage was simplified and the tonnage harvested per man-hour was increased.

The types of storage structures for hay and silage have also experienced some major changes. In two-story barns the reinforced concrete mow floor has been used to protect the dairy herd in case of fire. The ground-level hay storage structure was developed to provide low-cost storage and for protection from fire and windstorm losses. This low-cost structure may be adapted to the use of a drier or it may be filled by a conveyor, with hay that has been dried or conditioned in a crop drier building nearby. The important point is that this ground-level storage room has been found practical for stall barns and it may be used as a self-feeding barn for hay. When the building is constructed of noncombustible materials, fire risks will be reduced.

The tower type silo is a common sight on dairy farms throughout the northern and eastern dairy sections. It can now be emptied with a mechanical silo unloader directly into large, easy-rolling, side-emptying silage carts. In a few stall barns, newly developed conveyors are used to feed this silage to the cows. Mechanized outside feeding in the paved barn lot may be accomplished by using a conveyor in a feed bunk or by moving the feed bunk under the silo chute for filling.

Trench or bunker silos are used on some dairy farms. Small herds may be self-fed from this silo, but grass silage will require hand labor to keep the cows well fed. However, the percentage of losses tends to run high in small-capacity silos of this type. For larger herds the tractor-mounted fork and, in some cases, the self-unloading wagon are commonly used to fill bunks for self-feeding or to take silage to the stall barn.

It will be noted that self-feeding has been suggested, but in winter its use is mostly limited to herds in loose-housing systems. Free-choice feeding from well filled mangers of hay and silage means that the cows can wait on themselves and decide how much they need. However, when corn silage is fed in this way, the cows may have to be restrained in stanchions. It is suggested that when both corn and grass silages are fed they may be mixed and grain may also be added. The dairyman can judge the feeding operation according to how well the herd has cleaned up the last feeding. When roughages are plentiful, varied, and of high quality, grain or concentrate feeding may be reduced.

There is need for more studies on the utilization of freshly ground grains to improve the palatability of grass silage. Except for a few fresh, high-producing cows, dairymen could omit concentrate feeding while the cows are being milked. High-producing cows with good appetites will eat more roughages and thus get more concentrates. Under such a program it would be possible to handle the entire high-producing herd as a unit or as separate groups. If found practical, grain feeding in the milking room could be minimized to the point where it would not slow down the milking operation. Fortunately, except for breeding and calving times, the dairy cow, under loose housing, is easily managed, seldom goes off feed, eats heartily, and sustains few injuries.

Loose Housing

The loose-housing system has been developed for the efficient production of uniformly high quality milk by high-producing dairy cows at the lowest possible cost. For the successful operation of this type of dairy cattle housing,

certain requirements must be satisfied. For example, an adequate supply of bedding is a critical requirement, especially in northern climates.

Early in the studies of loose housing at the Wisconsin station it was observed that sudden temperature drops (one to a low of 23° F. below zero in the resting area) caused no drop in milk production. This was surprising and immediately raised the question as to what sort of tolerance to temperature changes the dairy cow actually possessed.

To determine the cows' response to different environmental conditions, a climatic laboratory was constructed at the Missouri station with USDA participation and was placed in operation in March, 1948. The findings have confirmed the full-scale herd tests on loose housing, which indicated that cows might be expected to produce as well in weather having daily low temperatures near 0° F. as they did on days having low temperatures of 40° F. and above. In the Missouri studies, signs of stress and loss of production started to show up as temperatures moved upward, starting at 75° F., with a 20% drop in production at an average temperature of 85° F. under a diurnal rhythm of temperature changes in the 70°-100° range. Critical conditions occurred at constant temperatures between 95° and 105° F. for European breeds. Cows produced as well at the 10° to 40° F. range of temperatures as at the 40° to 70° range. Hair and skin on acclimated cows afforded considerable protection when the animals were placed under low temperatures.

The milking parlor or milking room with elevated milking stalls, sometimes used on family-sized farms having stall barns, soon proved to be a necessary part of the loose-housing system. The milking room, when heated, provides a clean, pleasant, and safe place for milking cows. When all or a part of the concentrate ration is fed during milking, conveyors may be arranged for automatic feeding. Since cleaner milk can be produced in milking parlors having no grain feeding, as indicated by the presence of grain particles on strainer pads, feeding grain mixed with silage should offer a method for improvement.

The Stall Barn

The stall barn has had numerous benefits from research, efficiency studies, and mechanization. Good planning of these barns has been provided by extension engineers, barn equipment manufacturers, and materials dealers. Horse stalls gave way to more and larger cow stalls, perhaps for larger dairy cows—cows with more months of well filled udders, as contrasted with the average milking cows of 50 years ago. Long stalls and large tie-type comfort stalls that are equipped with electric cow trainers tend to reduce injuries and make cows more comfortable. Long stalls with cow trainers are effective in keeping the cows clean and preventing them from lying on bare floors and over the sharp edges of the gutters, as cows tend to move forward when lying down in the long stalls.

Thermostatically controlled, electrically operated ventilating fans of generous capacity are now available for barn ventilation. Such fans reduce odors, dust, and humidity. This ventilation system relieves the owner of the chore of providing supplemental ventilation for temperature control in all but mild winter weather. Heat exchangers have been developed for use in cold climates to salvage heat in exhaust air by using it for tempering incoming air. Safe, automatic heaters are inexpensive and may be used under unusual or extreme weather conditions.

Labor-Saving Devices

Silo unloaders can be used to fill large silage carts. Powered carts with side-unloading arrangement are now being considered. Hay and silage conveyors have been placed in use. A conveyor system for the individual feeding of concentrate ration to each dairy cow has been developed. Cows may be released in the morning to spend the day on a paved barn lot where they may be fed and held for milking; for their protection and comfort a bedded shelter may be provided. This method of combined stall and loose housing for dairy cattle may prove to be very acceptable in sections where dairymen are desirous of having many of the advantages of both systems. In summer, cows may be milked direct from the barn lot.

Barn cleaners help to keep the barn and the cows clean. Even the dairyman's clothes benefit in this regard. Cleaners have become an indispensable part of the larger dairy barns in northern areas, where the housing season is 6 months or longer.

Grain and concentrate rations can now be proportioned, ground, mixed, and conveyed to each individual cow's manger with no lifting or measuring by the operator. For free choice feeding operations, equipment for proportioning and mixing grain with silage needs further study, although for large-scale operations it can now be accomplished with self-unloading and mixing wagons.

Bulk milk production may be limited to the use of a bulk tank; it may include a C.I.P. milk line over the stalls or in a milking room. However, for smaller herds, the dairyman will, no doubt, continue to milk in his stall barn, if he has one. New developments in milking room equipment and arrangement will win the support of small herd owners who must build or remodel.

Engineers have developed more efficient stall-type dairy barns, and chore time has been reduced through good planning and careful selection of equipment. Thorough ventilation, insulation, and lighting make the stall barn

a more pleasant place to work. If desired, new barns may be constructed of low-cost, one-story units with connecting silo, hay, and bedding storages.

Another step in labor saving for the dairy farmer is the cleaned-in-place (C.I.P.) sanitary milk line when teamed up with the refrigerated bulk milk storage tank. The fluidization of milk production was completed by using an insulated bulk milk tank mounted for highway transport. As if decreed by fate or, more likely, owing to modern methods of market analysis, stainless steel of the 18-8 type, a noble metal in every sense, had been placed in large-scale production just prior to the development of bulk milk handling on dairy farms. Milk sanitarians had come to appreciate fully the advantages of using stainless steel for all milk contact surfaces. The first step is now being taken on a broad national scale in the conversion to bulk milk production through the installation of bulk tanks. The installation of C.I.P. milk pipelines of either stainless steel or heat-resistant glass has already started, and, although they may be installed in stall type barns, in some instances the greatest over-all benefit will be realized when the elevated stall milking room is constructed first. It is less expensive to install and clean the short pipeline that is used in the sanitary milking room. However, unless milking rooms have holding areas for groups of cows or the entire herd before and after milking, cows being released and tied in a stall barn will require an extra worker at milking time.

Cooperative Research in Dairy Farm Engineering

Research in dairy farm engineering has been conducted on a broad front, especially for the past 15 years. Some important advancements have been made. This work has required the fullest cooperation of many interests. The United States Steel Corporation started work at the Wisconsin and Utah Stations by supplying buildings and equipment. The Wisconsin Utilities Association supplied a farm and farmstead where stall barn mechanization studies have been made. National Steel entered into similar cooperative agreement with the Michigan Experiment Station. The United States Department of Agriculture has cooperated on many projects, including the Missouri Climatic Laboratory. The North Central Regional Technical Committee on farm building research has allotted funds from the Agricultural Research and Marketing Act to aid studies on various aspects of dairy farm engineering in several states. A farm building plan service is being maintained in each region to aid dairymen in applying the latest advancements in dairy farm engineering. Many state and local specialists, fieldmen, and inspectors are constantly helping farmers improve their physical plant and its operation.

At the Wisconsin station full cooperation between interested subject matter departments was established from the inception of the study. The writer, a member of the Regional Technical Farm Building Research Committee, served on the station research committees which at times included representatives from seven subject matter departments and on some occasions consultants representing the International Association of Milk and Food Sanitarians, and Public Health representatives at federal, state, and municipal levels. This work resulted in research reports which indicated the possible advantages of bulk milk production. Following this research, field studies were made on early bulk milk routes, and a publication on bulk milk production was prepared by a committee of 14 members representing five subject matter departments, and their consultants consisted of a committee representing the Wisconsin Dairy Federation, representatives of the State Board of Health, the State Department of Agriculture, and the state agency responsible for weights and measures regulation and enforcement. So quick was the response to these studies that the first edition of the publication was exhausted in something like three months. Dairy farmers were attempting to make a decision on converting to bulk milk. Commercial dairy farmers have thus indicated their awareness of the need for advancements as soon as research is able to supply the leads.

Dairy Farm Specialization

Milk production has come to be a highly specialized farming operation. It is a 7-day-a-week responsibility. The increased labor efficiency and freedom from drudgery made possible by the mechanized stall barn and the well planned loose-housing system has led to increased herd size and increased production per cow on the productive family-sized farm. Once he has specialized, the dairyman has more time to produce better feed for his animals and to produce milk of high quality because the number of operations he must do will be reduced as he eliminates other lines of business. His work will be easier. Better herd management will result in improved production. Under such conditions more efficient dairy cattle housing and improved equipment will be of greatest benefit in the production of the low cost milk of the near future.

The importance of the above statement becomes apparent when one considers the recent sharp drop in farm numbers from 5,382,162 in 1950 to 4,782,393 in 1954. In this same period farm size increased from 215.3 to 242.2 acres. Should this trend continue, more dairymen will soon be forced to choose between going out of business or swinging over to more efficient operations which will permit herd

size increases necessary to replace a part of the displaced herds and to consume the roughages and feed resulting from increased farm size.

Future

If we may be permitted to look into the future we will see indications that the opportunities to achieve greater efficiency in caring for a dairy herd and in producing milk are both numerous and promising. In the first place there are new and recent developments that only remain to be put into practice. Furthermore, many dairymen lag in the application of numerous advancements capable of increasing dairy efficiency. The farm has been found to benefit from many of the same advances that aid in increasing efficiency and reducing costs in industry. Here are a few possibilities:

Automation is being used in industry to lower cost and improve the product. Undoubtedly, the impact of automation will be felt on the dairy farm, where its application may be expected to produce similar benefits. We are certain to see more push buttons, more electronic controls, and new and better methods of preserving and processing concentrates and roughages. Improved practices in milking, milk production, utensil cleaning, and general sanitation will be developed.

The dairyman should have some days free both for business and for pleasure. Dairy herds are increasing in size about as rapidly as new labor-saving improvements are made available. This tends to increase responsibilities. The two-family farm partnership may solve the problem in some cases. Cows may be sent to a community boarding dairy home for their lactation periods. When dairy chores become further simplified through new advancements in technology, the job of relieving several dairymen by doing their chores one or two days a week and for their vacation may become a more profitable occupation than attempting to operate a unit that is too small to be profitable. The dairy farmer needs sufficient income to permit the establishment of this practice, and it may well come from higher producing cows and/or increased herd size.

Dairy farm finance will require drastic changes when milk surpluses vanish, in order to permit continuity in herd composition and milk production. Young or new dairymen will have to be started at a level approaching an economical size of herd. They will need an efficient building arrangement and adequate equipment. Even with help in obtaining credit, new dairymen will need to be well trained in dairy farm management if they are to succeed.

More care and attention will need to be given to dairy farm buildings and the equipment they contain. Only in this way can full benefits be obtained from the many improvements in management that will be made available through research and development in the years ahead.

Stall barns will be operated at moderately lower temperatures, thus keeping cows acclimated enough to cold to permit daily exercise out-of-doors, except in extreme cold weather. Where bedding is usually in short supply, cow stalls will be equipped with cushioned rubber pads and any available litter will be placed in the gutter. Some stalls in most barns will be equipped with heated pads for use by cows requiring this additional protection.

Dry lot feeding the year around with green feeding in grass-growing seasons will come to be a widely accepted practice. Silos will be used to absorb the difference between supply and demand as the crop season progresses. Irrigation in humid regions will also grow in usage. The net result will be greater yields of better roughages.

Herd size will be determined for efficiency in production. Dairymen interested in keeping the rate of production within the capacity of the population for the consumption of milk will find it to their advantage to strive for increased production per cow and thus obtain their income goal by balancing income and costs on a herd with fewer cows. This will also reduce housing costs and release money for initiating better methods and practices.

It also should be pointed out that there is need for renewed effort in research and development activity in the large overlapping area of joint responsibility between the dairy scientists and dairy farm engineers. The time has come to elevate dairy farm efficiency to the levels reached in other phases of farm production. The more the engineer knows about the exacting needs and responses of the dairy cow to environmental factors, kinds, and types of feeds and roughages, methods of handling, sanitation, and other pertinent criteria, the more effective his designs can be. The determination of such facts and the collection of the needed data can be obtained most effectively through integrated research, design, and operational projects by the groups concerned.

Fifty Years of Progress in Dairy Farm Sanitation

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By 1906 dairy farm sanitation regulatory activities had been inaugurated by a number of municipalities, particularly in the more heavily populated states. But the number of American communities with populations of 100,000 or less that had established full-time and adequately staffed public health departments, by that date, was relatively small. Consequently, a great many of the dairy farms supplying market milk were subject to no sanitation control whatsoever.

C. A. Abele

It is readily apparent that a description of 1906 dairy farm conditions, drawn 50 years later, cannot be strictly applicable to milksheds in which regulatory activities had been applied for any period, nor to all of the dairy farms in milksheds in which sanitation was wholly dependent upon the hygiene consciousness of individual milk producers. With that understanding, the state of dairy farm sanitation prevailing in most milksheds 50 years ago may be summarized as follows:

Except in older milksheds, conditions and practices had progressed beyond the stage of the family cow or small-herd operation only to the extent of the additional facilities necessary for producing and marketing the increased volume. Cows and horses—and sometimes swine and chickens—were stabled together. Barns were poorly lighted. Manure was commonly allowed to accumulate, usually in the barnyard, until plowing time. Milking pails were open-topped and were constructed of tinned sheet-metal, with lapped seams. They were often washed with the cooking utensils and tableware in the farm home kitchen. Washed utensils frequently were inverted over fence posts or pickets, or placed on a table or bench on the sunny side of the house, to drain and dry. Bactericidal treatment, when practiced, consisted of "scalding" with "boiling water." Milk cans were filled in the aisle behind the cows. The technique of cooling the milk, when practiced, varied with the climate. When cold water was available, cans of milk were set in it. In warm climates, manufactured ice was used (sometimes incorrectly). If a milkhouse was provided, it was customarily situated close to the residence and well, or consisted of a transformed feed-room in the barn. It sometimes was provided with a screened bay on the south exposure, in which milking utensils were "sunned." The well and family outhouse, in numbers of instances, had been sunk or built when sanitation was unknown. Tuberculin-testing of cattle was entirely voluntary. Bacterial plate count limits, when maxima were fixed by ordinance, ranged from 100,000 to 1,000,000 per milliliter, and the percentage of counts falling under the fixed limits was conceded to be low, particularly in summer.

It is not necessary to enlarge upon the public health significance of the degree of dairy farm sanitation indicated, which applied in the main to sources of milk for retail raw distribution.

The advance in dairy farm sanitation that has been made in the past 50 years can be measured by the difference between each of the conditions or situations described above and its 1956 counterpart. Readers who are personally acquainted with the current state of dairy farm sanitation are in position to make such a comparison. Others may make use of a widely accepted numerical index to denote the current state of dairy farm sanitation in specific milksheds.

Dairy Farm Sanitation in 1956

The nature of this numerical index and its meaning may not be clear to some readers. By means of unannounced inspections of a representative number of dairy farms in a milkshed, an indication of the general state of sanitation is obtained. Arbitrary values ascribed by the U. S. Public Health Service to each item of sanitation prescribed for Grade A Raw Milk (total 100) are multiplied by the percentage of the total volume of milk produced by the inspected farms that comply with each item of sanitation. The sum of these values is a numerical figure that cannot exceed 100 and that provides an index of the degree of approach to perfection in dairy farm sanitation in that milkshed. This figure is known as the Raw Milk Sanitation Rating. A rating of 90 or higher is accepted as an index of a practical degree of compliance with sanitation and average temperature and bacterial count requirements. Not all milk sanitation ratings made by State Health Department or Department of Agriculture personnel are reported to the U. S. Public Health Service, particularly when milk is not shipped or distributed out of the state. Nevertheless, the number of municipal and county raw milk sanitation ratings of 90 or above on file with the U.S.P.H.S. on Jan. 1, 1956, was 325. On the same date, the raw milk supplies of 410 companies located in 34 states had been certified to the National Conference on Interstate Milk Shipments to have raw milk sanitation ratings of 90 or more. It may be presumed that if the current status of dairy farm sanita-

tion in milksheds in which milk legislation other than that recommended by the U.S.P.H.S. is in effect were determined in a parallel manner, a comparable level of dairy farm sanitation would be revealed.

The effect of the sanitation programs of the Evaporated Milk Association, of individual member organizations of the American Butter Institute, of the American Dry Milk Institute, of the National Cheese Institute, and of numerous cooperative dairy products manufacturing operations upon the status of dairy farm sanitation in their respective milksheds should not be overlooked. New producers of market milk are usually recruited from those supplying milk for manufacturing purposes, and it is the general experience of regulatory sanitarians today that the transition is, in an increasing proportion of instances, not a major undertaking.

Factors Affecting the Advance in Dairy Farm Sanitation

The advances in dairy farm sanitation, in the various municipal milksheds, have been heavily influenced by a number of factors other than technological developments in sanitation. Terrain, climate, and land values have determined the agricultural and dairy industry economies of milksheds. Local custom and precedent determined the ease with which innovations in sanitation practice could be introduced. The ratio of regulatory and fieldmen personnel to the number of farms in, and the area of, the milkshed had an obvious impact upon the intensity of educational and quality control activities. The relative percentages of raw and of pasteurized milk being distributed when regulatory control was instituted will have determined the degree of emphasis placed upon dairy farm sanitation then, and subsequently maintained. And the attitude of milk consumers will have been reflected in the support accorded regulatory officials and in the continuity of appropriations for quality control activities.

Another factor, not included among those above enumerated, has profoundly influenced both the concept and the measure of dairy farm sanitation. From the time of its adoption, in 1908, by the Dairy Division of the U. S. Department of Agriculture, until well into the 1920's (later in some sections), the Official Dairy Farm Score Card was the universally used guide for dairy farm inspections, and the numerical score received by a farm was the recognized measure of its sanitation and was the basis upon which permits to distribute or to ship milk were issued. When introduced, the score card served to unify the instructions and requirements of fieldmen and regulatory sanitarians. But a study conducted in 1914-15 failed to reveal a clear relationship between dairy farm scores and the bacterial quality of the milk produced. In 1921 the Official Score Card was severely criticized on a number of counts, the chief of which was the charge that there was no provision for immediate exclusion of milk from the market as long as the total score exceeded the minimum fixed in that market.

In 1922 the State Health Officer of Alabama requested the advice and assistance of the U. S. Public Health Service in the development of a program to provide better and safer milk. Only small percentages of the milk supplies of the few larger cities were being pasteurized at this time. The program evolved consisted of the development of a milk ordinance, adoption of which was to be urged upon municipalities. This ordinance, in addition to the sections common to such legislation, set forth rather specifically the sanitation requirements and fixed maximum average temperature and average bacterial counts, mandatory for the production of Grade A Raw Milk and Grade A Pasteurized Milk. Some of the requirements for Grade A Raw Milk were of debatable public health significance but were of a nature which it was assumed informed homemakers would demand —could they make inspections—of the sources of milk served their families. It made mandatory the labeling of each container of market milk—on the bottle cap—with the grade of the contents, grades other than A being determined by the extent of noncompliance with the requirements for Grade A or by the range into which the average temperature or average bacterial content fell. This milk ordinance was unique in several respects:

1. It provided a commercial incentive for milk producers and distributors to adopt top-level dairy farm and milk plant sanitation.
2. It enlisted the aid of consumers in encouraging distributors to provide milk of Grade A quality.
3. It placed upon regulatory agencies the responsibility for inspecting dairy farms and milk plants and for taking samples with sufficient frequency to enable them to announce the grades of all milk supplies at prescribed intervals.
4. It substituted logarithmic for arithmetic averages of bacterial counts.

The principle of grading milk supplies on the basis of sanitary quality was ideally suited to milksheds that had no history of quality control, since it provided each producer-distributor and pasteurizing plant with the time needed to conform to requirements for Grade A —provided the milk was plainly labeled with the grade into which its production or processing environment, or average temperature or bacterial count, placed it. The penalty for procrastination in conformance to requirements for Grade A was the difficulty in meeting the competition of those who did comply.

Considerable academic opposition to the philosophy of this milk ordinance was expressed

by some regulatory authorities because it permitted Grades B, C, and D raw milk to be marketed. Completely overlooked by these critics was the fact that the same milk placed in Grade B, C, or D by application of this milk ordinance had obviously been available to consumers prior to its adoption; also unrecognized was the fact that shortly after Grade A milks were available in a market, consumers were reluctant to have it become known that they were having sub-grade milk delivered to their homes. Beginning in 1924, the Alabama example was followed by neighboring states, and by 1927 this milk ordinance, modified in minor details, had become the U. S. Public Health Service Milk Ordinance. By Dec. 31, 1955, it was in effect as ordinance, board of health regulation, or statute in 1,599 urban communities, in 422 counties or parishes, and in 34 states and 2 territories.

In 1927 a code of interpretation of the items of dairy farm and milk plant sanitation mandatory for Grade A Raw and Grade A Pasteurized Milks was published. It presented both the public health reason for, and an outline of satisfactory compliance with, each item. These detailed directions for regulatory sanitarians, coupled with the wide adoption of this milk legislation, have provided the avenue through which the technical developments of the latter three-fifths of the 50-year period under discussion have been applied in the areas covered by the statistics presented above.

Effect of Technical and Organizational Developments

Technical developments in sanitation science have had an important influence upon dairy farm sanitation. So many members of the American Dairy Science Association have had a part in these developments, or have devoted long, active lives to the instruction of those connected with the maintenance of dairy farm sanitation, that space is not available to name and credit them individually.

Assay of milk quality. Plate and microscopic count and methylene-blue and resazurin reduction test techniques, the last three of which were developed during the past 50 years, are all being employed as indices of bacterial content of milk supplies. These tests have had a direct effect upon dairy farm sanitation, whether employed as one of the determinants of the grades of milk supplies, as the basis for exclusion of supplies, or in diagnosis of the nature of lapses in dairy farm sanitation. The standardization of procedures for the determination of the bacterial quality of milk was inaugurated in 1905 by the appointment of a committee of members of the Laboratory Section of the American Public Health Association, which was instructed to determine reliable procedures. The first edition of *Standard Methods for the Examination of Dairy Products* was published in 1908; nine other editions had been published by 1953. A number of members of the A.D.S.A. played an active part in studies that determined the changes made in successive editions.

Probably the most far-reaching effect which any method for estimating the bacterial content of milk has had upon dairy farm sanitation resulted from the change prescribed in the composition of the culture medium for the plate count and the lower incubation temperature permitted by the seventh (1939) edition of *Standard Methods.* The prescribed medium was changed from standard nutrient to tryptone, glucose, beef extract, and milk (TGEM) agar and the incubation temperature from 37° to 35° or 32° C., as desired. The more numerous countable colonies produced in 48 hours by the new technique resulted in higher plate counts and necessitated devotion of greater attention, by all concerned, to dairy farm sanitation.

Evaluation of sediment test pads has been standardized by the availability of photographs of discs obtained by straining water containing known concentrations of a standard mixture of contaminants. The educational activities of manufacturers of strainer discs have been influential in promoting better milking and milk-handling practices.

Control of bovine diseases. The public health hazard incurred by the consumption of milk from diseased cows has decreased proportionately as the percentage of the total milk supply that is pasteurized has increased. However, even though the entire fluid milk supply be pasteurized, sound administrative public health precautions justify the retention in milk legislation of the provision that only healthy cows be milked.

The control of bovine tuberculosis in dairy herds, to the extent that this disease could officially be declared virtually eliminated by Dec. 31, 1942, was an outstanding achievement, in which the Bureau of Animal Industry of the U. S. Department of Agriculture played the dominant part, but in which State Livestock Sanitary Boards, regulatory sanitarians, fieldmen, extension dairy specialists, practicing veterinarians, and producers collaborated. In a number of states, incidence of this disease is so low that area tests are now conducted at 6-year intervals. The national rate of reactors found was announced to be 0.11% on Jan. 1, 1956. Nevertheless, the occasional discovery of bovine tuberculosis in dairy herds lends support to the insistence of some regulatory authorities that herds be tested more frequently.

Control of brucellosis is progressing rapidly, primarily because control measures are becoming mandatory in so many milk ordinances. Organized application of the ring test, the testing and slaughter of reacting animals, calf vaccination, and support of the program by federal appropriation are resulting in reduction in the incidence of this disease. Approximately

15 reactors were found per 1,000 tested during 1955.

Success in the control of mastitis has been variable. The managed milking technique encourages the practice of good hygiene, which may be expected to result in early diagnosis and treatment.

Milking utensils and equipment. It has been the recurring experience of successive generations of milk sanitarians that the installation of labor-saving devices often results in milk of poorer bacterial quality. Milking machines came into scattered use prior to 1920. Their numbers increased with the extension of rural electrification, and their use became almost universal with the shortage of labor that has existed since the beginning of World War II. The design, construction, and finish of early models were aimed at utility, with a minimum regard for ease of cleaning. The literature includes as many papers on the care of milking machines, rubber parts, and vacuum pipelines as are to be found on any other single sanitation subject. The solution of this particular problem in dairy farm sanitation may entail the wider mechanization of the cleaning operation.

The movement of milk through pipelines, from milking machines to cans or batch pasteurizers, has been practiced in milking parlor operation since the early 1930's. But such piping had to be dismantled for washing and reassembled in preparation for milking, requiring time and labor barely balanced by the elimination of the manual movement of each machine pailful of milk to the milkroom. Acceptance by milk sanitarians of the principle of circulation cleaning, initiated in milk plants, has given impetus to the installation of milker pipelines to reduce milking and clean-up labor. Pipeline milking represents an advance in dairy farm sanitation, provided the piping is properly installed and is effectively cleaned and sanitized in place. The occasional development of rancidity in milk handled in this manner is currently being charged to faulty installation or operation, because of which violent agitation of the milk occurs.

The recent trend toward the cooling and storage of milk in bulk tanks at the farm may have a beneficial effect upon quality. This system eliminates the potential bacterial contamination contributed by ineffectively cleaned milk cans and increases the rate and extent to which the milk is cooled. The effects of both of these factors are in the direction of reduction of bacteria. The bulk tank system would be of limited economic advantage if the milk were not also transported from farms to receiving stations in bulk. There has been a rapid adoption of this method of collecting milk, in spite of the disturbances effected in conventional hauling and receiving procedure. The elimination of the opportunity to take platform samples of each producer's milk is of considerable concern to regulatory authorities. This situation may eventually lead to the deputization of fieldmen and pick-up tank-truck drivers to take official samples at dairy farms. And—if dairy farm sanitation requirements are retained in milk ordinances—it will necessitate greater emphasis upon dairy farm inspection by the regulatory agencies which have heretofore relied principally upon platform examinations and tests as indices of conformance to mandatory features of dairy farm sanitation.

Detergents, bactericides, and insecticides. Cleaning of equipment has been advanced materially during these 50 years by the progressive improvements made in dairy detergents. This has been accomplished by the incorporation of sequestering, dispersing, wetting, and chelating components and by the development of acid detergents. Recently, chlorine compounds have been incorporated into alkaline detergents to improve their effectiveness.

Milk legislation universally prescribes sterilization, disinfection, bactericidal treatment, or sanitization (as the process has progressively been termed) of washed equipment. Initially, this treatment consisted of "scalding," or momentary exposure to a jet of flowing steam. The next development consisted of steaming or heating equipment in a closed chamber. In 1919 the rinsing of washed equipment with a solution of calcium hypochlorite was proposed. The turbidity and layer of precipitate formed in such solutions led to the marketing of concentrated sodium hypochlorite. Subsequently, chlorinated trisodium phosphate, quaternary ammonium compounds, organic chlorine complexes, and iodophors have come into more or less general use. The development of the Weber-Black technique for determining the degree of "kill" of bactericidal solutions has provided a more reliable index of germicidal effectiveness, at use concentration, than the phenol coefficient and has provided concentration and kill-time standards for bactericidal solutions.

Combinations of a detergent and a bactericide—termed detergent-sanitizers—have been a development of the past 5 or 6 years. Acceptance by regulatory sanitarians of the principle of performing, in one operation, functions that have traditionally required two distinct operations, has been varied. In many instances, interpretations of milk legislation preclude recognition of cleaning and bactericidal treatment as a single operation. In other instances, the many opportunities for the recontamination of manually washed equipment, particularly during reassembly for use, deter sanitarians from permitting the use of such products, unless bactericidal treatment after assembly is also practiced. The solution-circulation method of cleaning equipment that can be closed after washing may bring about the wider acceptance of detergent-sanitizers. The solution circulation technique for cleaning and sanitizing equipment in

place in milk plants has been applied to milker pipelines with generally satisfactory results.

The control of flies of all types around dairy farm structures is a year-around operation in some milksheds and a seasonal one elsewhere. Prior to the advent of residual insecticides, fly-control measures included sanitation of the surroundings, augmented by arsenic poisons, baited or electrically-charged traps, and cattle- and space-contact sprays. The enthusiasm with which residual insecticides were received and endorsed by milk sanitarians was unbounded, and the chagrin and consternation felt when strain after strain of flies developed immunity to one after another of these residuals were equally boundless. As a consequence of this discouraging development, fly-control on dairy farms has reverted to emphasis upon sanitation, contact sprays, and poisons—now organic phosphates.

Dairy farm structures. It is axiomatic that the location, dimensions, lighting, ventilation, construction, and facilities of milkhouses have a significant impact upon dairy farm sanitation. To encourage milk producers to incorporate desirable features in plans for milkhouse construction or remodeling, plans and lists of materials required have been prepared and distributed. About 10 years ago the regulatory authorities of several Middle Atlantic states collaborated in drafting milkhouse plans, preferably to be followed in those states.

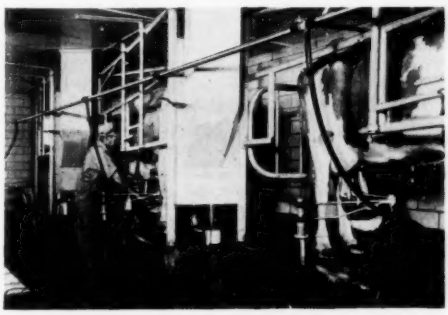

FIG. 1. Automation is an important phase of sanitary milk production.

Milking parlors, except with respect to arrangement, equipment, and finish, are not a recent development. Throughout the Deep South, in the Southwest, and in California, dairy barns, even though of substantial and tight construction, are occupied only during the milking operation except in extremely severe weather. Thus, although not provided with elevated cow-stands, walk-in or walk-through stanchions, or carry-away milk piping, these barns are essentially milking parlors. The herds are loose-housed, in that they are kept in the barnyard over night or confined at all times in a large corral.

Loose housing, as opposed to the confinement of cows in stanchions, is growing in popularity in some areas in which dairy herds have to be sheltered during a portion of the year. It is claimed to reduce the incidence of traumatic damage to udders and otherwise to improve the health of herds. But, in order to assure and facilitate conformance to sanitation requirements, regulations of this practice in some cases prescribe prerequisites, such as impervious floors, accessibility for mechanical cleaning equipment, ample bedding, and other feeding and watering areas.

The rates at which pipeline milkers and milk cooling tanks are being installed, and loose-housing is being undertaken, portend a growing trend toward the use of milking parlors, which presumably will further advance the level of dairy farm sanitation.

FIG. 2. Rapid cooling of the freshly drawn milk to near 40° F. is accomplished on the modern dairy farm by means of bulk milk cooling and storage tanks.

Value of Educational Agencies

An increasing proportion of regulatory sanitarians and fieldmen is now being recruited from graduates in veterinary medicine or dairy technology, and in a few states schooling of this nature is a mandatory prerequisite for employment in such capacities. It is obvious that regulatory agencies are considerably indebted to the faculties of dairy schools, the staffs of experiment stations, extension service dairy specialists, and vocational educators for many of the advances in dairy farm sanitation voluntarily made by milk producers as the result of their educational activities. Also, the contributions in this field made by dairy and farm journals and county fair displays should not be overlooked. Nor should the instructional

activities of manufacturers of barn and milking equipment and of dairy detergents and bactericides, as well as their research and field tests, be ignored or discounted.

Voluntary organizations. Contributions to the advance in dairy farm sanitation made by voluntary organizations have been appreciable. The mere naming of some of these organizations will serve to remind readers of the ways in which their activities have contributed: 4-H Clubs, Future Farmers of America, Dairy Herd Improvement Associations, Dairy Technology Societies, the International Association of Milk and Food Sanitarians and its numerous state affiliates, the American Association of Medical Milk Commissions, the several Breed Associations, and the American Dairy Science Association.

Extension Work in Dairy Production

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Fifty years of dairy production extension work have brought many changes in subject matter, in the methods of presenting it, and in the ways of traveling to meetings. Farmers' institutes, which had been in existence before 1906, continued to be, in many states, the principal method of doing dairy extension work until the passage of the Smith-Lever Act in 1914. This type of instruction had its limitations, largely because there was no "follow-up" to assure result demonstrations of the practices that had been suggested at the meetings of the institutes.

E. C. Scheidenhelm

In 1905, the year before our scientific association was organized, events happened that helped open the door for the development of the dairy extension program. Helmar Rabild, then of the State Department of Agriculture in Michigan, organized the first dairy herd improvement association in Newaygo County. During the same year an intensive effort was started to bring added agricultural income to the southern states by improving the dairy industry of that section of the country. This was the real beginning of the dairy extension work of the South, as stated by J. H. McClain in his final report when he retired in 1920 from this regional type of extension work conducted by the Bureau of Dairy Industry. All of the financial aid and all of the workers were provided directly by the federal government for the early years of extension.

Some states were indifferent to the federal assistance provided them. In fact, the U. S. Department of Agriculture withdrew personnel from several states in which state college or university officials failed to give financial support to the work that had been started. This brought a marked delay in an effective dairy extension program in these states.

With the passage of the Smith-Lever Act in 1914, dairy extension work started to function as it is known today. The state colleges and universities began to provide the workers, and the Dairy Division of USDA began to withdraw its assistance to the southern states as quickly as each of them saw fit to develop the work on a cooperative basis.

The other regions of the country also saw the value of adding specialists who were trained in dairying, and, in most of the major dairy states, proper provision for such a worker was arranged at an early date.

The period from 1914 to 1920 was one of securing staff members to handle dairy extension work. Emphasis was placed largely on developing feeding programs and on organizing cow testing associations. In a few states cooperative bull associations were formed.

Extension Gains Momentum after 1920

With the advent of the "roaring 20's" production work in dairy extension came into "full bloom." There were several reasons for this. One worthy of mention came after the name, Dairy Instructors Association, was changed to the American Dairy Science Association. The dairy extension workers were invited to participate in the activities of the enlarged organization. Prior to the annual meeting of A.D.S.A. in 1921, the dairy specialists had their own organization, known as "The Association of Extension Workers in Dairying." As a result of this new affiliation more definite programs were developed in each state. In 1922 the following committees were established in the extension section of A.D.S.A.: cow testing associations, bull associations, calf clubs, milk campaigns, and dairy products. In the same year the official testing section began to handle the breeds relations work.

Milk Campaign work was one of the popular projects in the early 1920's. Assistance with the program was given to the states by the Division of Dairying of the USDA. As an example of its efficiency, Miss Jessie Hoover, then of USDA and also the chairman of the A.D.S.A. milk campaign committee, reported at the annual meeting on October 10, 1922, that milk consumption in Madison, Wisconsin, had been increased 25% within one year.

Research work had expanded rapidly during the 1920's and had provided needed data for additional extension teaching. As a result, the extension section of A.D.S.A. added the following committees: cost of production, Dairy Council work, and feeding. Dairy 4-H Club work was emphasized especially during the last half of this same decade. As a result many new herds were developed using 4-H animals as seed stock. Intensive pure-bred sire campaigns were launched in many states. As a result the scrub bull went to the butcher, and signs appeared along highways or on courthouse squares stating that 100% of the farmers in the county were using pure-bred sires.

Many states used "dairy improvement trains" as a manner of bringing successful dairy practices to the farmers. Very often, during scheduled stops of the train, a part of the program

was devoted to the trial of the scrub bull. Large numbers of farmers were reached by the train campaign; however, many institutions found that it was a costly operation.

Extension workers had found many organizations willing to help promote the dairy enterprise. It is well remembered that the second decade of the 1900's brought great concern with regard to providing an adequate food supply to meet the demands of the rapidly increasing population. Statistics indicated that the output of milk had fallen from 95.6 gal. per person in 1899 to 75.5 gal. in 1915. Subsequently, after World War I, dairying was promoted to the rank of one of the most profitable of farm enterprises and found many farmers ready to adopt it.

Improvement of Practices

Largely through the A.D.S.A. committees, production workers in dairy extension brought on needed improvements in recommended practices. About 1925 the program of "cow testing associations" was changed to "dairy herd improvement associations." The sire proving program was added as an aid to the breeding programs. This period also marked the beginning of the district shows sponsored by the breed associations.

The early 1930's were largely a continuation of the developments of the previous ten years. Through the leadership of USDA each state conducted the superior germ plasma survey. During this era there was also an awakened interest in improving the quality of milk produced on farms. Extension dairymen spent many hours explaining the value and demonstrating the construction of cooling tanks.

Much of the coordination and assistance to the dairy extension program was given during the 1930's and the early 1940's by the Bureau of Dairy Industry. This was accomplished by having four regional specialists who made periodic visits to the states. It was a joint effort of the "Bureau" and the Federal Extension Service.

Programs in production dairy 4-H Club work also were further developed. Many states made large-scale purchases of well bred calves, which were made available to boys and girls. The extension dairyman emphasized proper record keeping of the project work in addition to such practices as fitting and showing, judging, and exhibiting of the animals.

Then came 1937 with the World Dairy Congress in Berlin. After that meeting, E. J. Perry, extension dairyman of New Jersey, visited Denmark, and returned to the States with the new program of artificial insemination for dairy cattle. That method of animal breeding opened a new field in extension activities. It resulted in a chain reaction of organization developments, research studies, and new refinements in techniques, which have continued to this day.

Early in 1940 extension workers were presenting programs of correct milking practices. Milking machines had been widely adopted and skills were needed to use them properly.

Herd health was given greater consideration; the herd health committee of the extension section of the A.D.S.A. reemphasized the importance of this program. Much credit can be given to dairy specialists who have been instrumental in improving the health status of the dairy cattle population.

Then came World War II, with its great demands for food production. Here again production extension workers in dairying answered the call. A new emphasis was given to the feeding program for dairy cattle. Effort to obtain the most production per acre of land was the urgent cry of the time. Methods of preserving roughages with the most protein and other feed nutrients were especially emphasized. In addition, all management practices for increasing milk production were given foremost attention. Such recommendations as milk substitutes for calf raising, rotational grazing, and mastitis control were given a prominent place on dairy programs.

With the start of the 1950's and a declining agricultural price level, extension dairymen again brought into focus economical milk production methods. The present era has also demanded a reevaluation of sire selection methods. Extension specialists have played an important role in bringing about a better understanding to dairymen of the complex problem of attempting to evaluate both hereditary and environmental factors.

All of these developments have led to a closer working relationship between the members of the extension departments and the resident production staffs. Several of the committees of the A.D.S.A. have been joint committees equally represented by members of the resident and the extension sections.

It must be mentioned that, through the years, extension dairymen have gained much toward improvement of the dairy extension work through the close cooperative work of the dairy breed associations, the artificial breeding associations, and the general dairy organizations, such as milk producer groups and fieldmen for the dairy companies. Since 1914 the action programs set up in the counties by the county agricultural agents have made an invaluable contribution. Close follow-up work on cooperating farms has meant much to the successful adoption of recommended practices.

Teaching Methods

Since 1914, emphasis has been placed on the demonstration method of teaching by extension dairymen in field work. In addition, as new media have been developed they have been used in effective ways of reaching people. Radio was quickly recognized as a vehicle of communication by which more people could be reached

with less effort. Both audible and visual education were made possible through television. The A.D.S.A. Committee on Teaching Methods has encouraged the use of such visual aids as the flannel graph and the various types of picture slide equipment.

"Problem solving" as an approach to extension teaching has been receiving new emphasis. Dairymen have responded more quickly to solving their problems through this approach than by merely listening to an authority use the "practice selling" approach. Then too, extension dairymen have found that they have been engaged more and more in the job of "teaching teachers." Leaders have been trained in the counties to help teach others how they can solve their problems. This approach has enabled extension specalists to be a vital part of the "unit approach" method of doing extension work. Many states are giving more emphasis to in-service training of staff members.

Improved Transportation Speeds Extension Work

Since 1905, extension workers in dairy production have witnessed a striking evolution in modes of travel. Early workers spent many tiring hours traveling by train, horse and buggy, or even on foot. With the improvement of highways and motor car travel, the extent of the specialists' work was an impressive factor. Meetings were often held in two or three counties a day. One disadvantage arose, however, with these modern avenues of travel. The workers became pressed for time to study the current subject matter. Very often specialists spent their hours on trains or in dimly lighted depots gleaning from the literature new information to add to their teaching lessons. As a result, the specialists' time had to be carefully budgeted between field and office work to provide opportunity to pursue subject matter material. The trend now is for the specialists to prepare more and more material as teaching aids for the county agents to use in the field.

The advancement of 50 years of production work in dairy extension has been most fascinating. Sub-projects were developed by the specialists in order to put into practice valuable information gained from research findings. It has been pointed out that through these efforts dairy farmers were taught how to feed well balanced rations, to improve herds in type and production by improved breeding methods, and to use proper methods of milking, not only to maintain the health of the cow but also to produce a high quality product; disease control methods were adopted, management practices were improved and herd replacements were properly developed. During this period many inventions have helped the dairy specialist to present his information in an interesting way. The approach to his teaching methods has changed more and more from a practice-selling to a problem-solving method. Rapid strides in improved transportation methods have also helped him bring more information to greater numbers in less time.

Looking Ahead

In the future an expanded utilization of the artificial breeding program and of the refinements in the data to measure the breeding methods may be expected. Without doubt there will be an increase in the number of cattle included in the production testing programs. Environmental factors affecting the volume of milk will be given additional study.

It is apparent that the small dairy farm operation cannot continue to cope with the present economic trend. Thus, larger herds will be the answer, and the dairyman will be demanding the type of information needed to handle more intensive units.

The current amount of time spent in field work by the specialist will be reduced so that he can devote additional effort to program projection and planning. With less time in the field and more time in the office, he can prepare teaching aids and printed material needed by county extension workers.

Although the program of the past 50 years in dairy production extension has been most commendable, new methods in improving production testing programs, measuring breeding programs, planning successful dairy farm operations, and arranging dairy programs will make for even greater achievements in the next half-century.

Fifty Years of D.H.I.A. Work

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Dairy Herd Improvement Associations, formerly called Cow Testing Associations, have operated in the United States since 1906; hence a report of the developments over the last 50 years constitutes a complete history of the work. Credit for organizing the first Dairy Herd Improvement Association in the United States goes to a Danish immigrant, Helmer Rabild, and a small group of dairy farmers in Newaygo County, Michigan. Mr. Rabild knew what cow testing associations had meant to the dairy farmers in his native land, and he was convinced that a similar program would be of inestimable value to dairy farmers of his adopted country. As a consequence, he was instrumental in getting the first association organized. At the time, Mr. Rabild was employed by the Dairy and Food Division of the Michigan Department of Agriculture.

F. J. Arnold

The meeting that resulted in the organization of the first Dairy Herd Improvement Association in the United States was held on Sept. 26, 1905, and was attended by six or eight dairymen. After hearing Mr. Rabild explain the advantages of a production testing program, the group appointed a committee to set up the organization. The Association began operating in January, 1906. Thirty-one herds consisting of 239 cows were tested the first year.

News of this new development soon spread. In Michigan the number of associations increased to four in 1907 and continued to grow until 1926, when a peak of 108 associations was reached. The first two states to follow Michigan's lead were Maine and New York. Each organized its first association in 1908. Five states got started in 1909, four in 1910, eight in 1911, three in 1913, seven in 1914, one in 1915, two in 1917, three in 1918, three in 1919, and one in 1920. The last state was Florida, in 1929.

Except during the war years when supervisors were not available and during the depression of the 30's, the program grew steadily. On Jan. 1, 1956, 2,266 associations were operating (one or more in each state, Hawaii, and Puerto Rico). These associations were testing 40,984 herds consisting of more than 1,406,306 cows.

Through the early years, the moving force behind D.H.I.A. work was the Dairy Division of the U. S. Department of Agriculture. The attention of the department was attracted to the organization in Michigan, and in 1909 promotion of the program became a federal project. Mr. Rabild was employed to head the work, and under his leadership the program was carried to all the states.

In the states the organization and supervision of the program was under the direction or sponsorship of the state departments of agriculture or the state agricultural colleges, but by the time the Cooperative Agricultural Extension act was passed in 1914 the associations had become such a promising source of practical information that they were drawn into the state and federal extension programs.

Key Factors in the Development of the Program

In the early development of the D.H.I.A. program, the most important factor was the firm foundation laid by Mr. Rabild. He established a pattern of organization and method of operation that has stood the test of time. Through the years only minor modifications were made of the organizational set-up, and, although many changes were made in the regulations governing the operation, the basic rules have remained as they were.

Another important factor was the cooperative leadership and support given the program by its sponsoring agencies, namely, the Federal Dairy Division (which became the Bureau of Dairy Industry in 1924 and the Dairy Husbandry Research Branch in 1952) and the Agricultural Extension Service. This cooperation meant several things. In the first place it meant that the program would be organized and conducted on the same basis in every state. The pattern followed was, of course, the one outlined by Mr. Rabild. It also meant that the program would be nationwide in scope, but at the same time each state would have full control of its own program. Finally, it meant efficient operation of the program with the Federal Dairy Division assuming certain obligations and the states, others.

As the cooperative relationship between the Federal Dairy Division and the Agricultural Extension service developed and grew, the division of responsibility was at all times clear. But it was not until 1952 that a memorandum of understanding was executed. This agreement, now in effect in all states, clearly sets forth the purposes of the D.H.I.A. program and spells out in detail the responsibilities of all parties concerned, including the Dairy Husbandry Research Branch, the Cooperative Extension Service, and the Dairy Herd Improvement Associations.

The obvious value of production records in a dairy herd improvement program was reason enough for the D.H.I A. organization. However, if the early promoters had not had a broader view of its value, the development over the years probably would have been quite different. The early promoters of the program saw the direct value of production records to herd owners, but they also realized that all dairymen would benefit. This realization provided the stimulus and justification of the time and effort devoted to the program by the early leaders, and the same objectives justify the work of the sponsoring agents today.

From almost any point of view, the D.H.I.A. is an ideal result demonstration. The members of these organizations are dairy farmers who want information with which they can improve efficiency and increase profits from their herds, and they want it urgently enough to employ a man to compile the information. Furthermore, the records provide a detailed study of the dairy enterprise on each member's farm. The data thus obtained not only are valuable to the association member but also serve as basic information in educational meetings with other dairymen. Today a large part of dairy husbandry extension work is founded on the results of dairy herd improvement associations.

Of great importance in the development of the D.H.I.A. program have been the steps taken to keep the program on a uniform basis throughout the country. In this the American Dairy Science Association has played an important role. The important feature of this development was the establishment of a policy of clearing all matters pertaining to the operation of D.H.I.A. through the A.D.S.A. As questions arose or problems developed, committees were appointed to formulate recommendations. The recommendations were then discussed at A.D.S.A. meetings and by the democratic process were rejected or approved, thus making the A.D.S.A. the final decision-making body. The policy of working through the A.D.S.A. was started in 1924. That year a committee was appointed to write uniform rules for the operation of the dairy herd improvement associations. The rules were adopted at the annual A.D.S.A. meeting in 1925. Since that time the extension section of the Association has maintained several standing committees that have guided the developments of the different phases of the D.H.I.A. program.

A good example of the way changes were made or new phases were developed is the change in name. In 1926 the testing committee of the A.D.S.A. suggested that the name, "Cow Testing Association," did not adequately describe the functions of the organization. It proposed instead the more descriptive name, "Dairy Herd Improvement Association." At the annual meeting of the American Dairy Science Association in 1927, the change in name was approved.

The Proved-Sire Program

Undoubtedly, the development which has added to the value of D.H.I.A. more than any other is the proved-sire program. The plans for this were completed and approved by the A.D.S.A. in 1935, and the program got under way in 1936. Over a period of 10 years prior to the completion of the plans for a nationwide program, however, a procedure of proving sires in each state was encouraged, and a fairly large number of bulls were proved. Because of certain limitations, however, progress was slow. One of the limitations was the lack of adequate identification of cows. A large percentage of the cows being tested were grades, and few farmers had permanent identification records. Another limitation was the fact that, to a large extent, the records used in proving sires were those available in a single herd or at best in a single association. Furthermore, the work of proving the sire was the responsibility of the tester.

As a part of the nationwide sire-proving program a permanent identification system making use of coded eartags was inaugurated, and arrangements were made to establish a central record-keeping system in the Bureau of Dairy Industry, Division of Dairy Herd Improvement Investigations. This meant that the records on grade as well as registered cows from all parts of the United States could be assembled in one place and sires could be proved from records in several herds in as many states.

The experiences of sire proving prior to 1935 when the nationwide program was set up suggested other refinements that needed to be made. Prior to 1932, sires were proved by using the highest yearly records on both the daughters and dams. From 1932 to 1936, the highest 365-day lactation records were used. Both of these methods were admittedly faulty, and, when the new program started, comparisons were made by using 305-day mature equivalent 2 × records and all records available were used.

An indication of the significance of this development is the fact that prior to 1937 a total of 7,200 sires were proved throughout the United States. From February, 1937, when the new program got under way to July, 1955, a total of 50,000 sires were proved.

Leadership of Federal Workers Has Been Important

From the organization of the first dairy herd improvement association to the present, leadership and support of the federal Dairy Division have meant much to the development of the program. As a result of Mr. Rabild's early influence, the program has been established throughout the United States on a very sound basis. The influence and assistance of the Division was extended in 1929 when the Bureau of Dairy Industry and the office of Cooperative

Extension Work joined hands in providing dairy extension assistance in all parts of the United States. At about the same time, the division of Dairy Herd Improvement Investigations was established in the Bureau of Dairy Industry. This paved the way for a great expansion in the service which the Bureau could give the states in summarizing and analyzing D.H.I.A. records. A monthly D.H.I.A. letter has also come from the Bureau, the first publication being in May, 1925. With the development of the nationwide sire-proving program, the monthly letter took on added importance. Starting in November, 1940, one section of the letter carries a listing of all sires proved.

What the D.H.I.A. Program has Meant to Dairymen

As the name implies, Dairy Herd Improvement Associations help dairymen improve their herds. Association members benefit more than nonmembers, but directly or indirectly every dairy farmer has been helped by the program.

Production records may be used as guides for better breeding, feeding, and management. The extent to which they are used determines the amount of improvement made. An indication of the progress which D.H.I.A. members have made through the use of production records is shown in Table 1. Here the average production of cows tested in the first association in 1906 is compared with the average production of the cows tested in 1954. Also given is the average production of all the cows in the United States in the same years.

TABLE 1

Comparison of average production figures

	D.H.I.A. cows		All cows	
Year	Av. milk	Av. fat	Av. milk	Av. fat
	(lb.)	*(lb.)*	*(lb.)*	*(lb.)*
1906	5,300	215	3,646	146
1954	9,363	372	5,447	213
Increase	4,063	157	1,801	67

It may be noted that the cows tested in 1954 averaged 4,063 lb. of milk and 157 lb. of butterfat more than the cows tested in 1906. In contrast to this, the average production of all cows in the United States was 1,801 lb. of milk and 67 lb. of butterfat higher than in 1906. There was a substantial increase in the average production of all cows, but the D.H.I.A. herds increased nearly 2.5 times as much.

Because of the fact that many new herds join D.H.I.A. each year, the progress shown in the above table is not as significant as the progress made by individual herds. A study of herds tested continuously in Iowa showed an increase in average of butterfat production of 50 lb. from the first year of testing to the tenth year. This is an average yearly increase of 5 lb.

Another indication of the improvement that has been made in D.H.I.A. herds is a comparison of the number of cows at different levels of production. In 1926, 22% of the D.H.I.A. cows produced less than 225 lb. of butterfat annually, and only 6% produced more than 425 lb. That year the average production of all cows tested was 289 lb. In 1953 only 7% of the D.H.I.A. cows produced less than 225 lb. of butterfat, and more than 24% of them exceeded 425 lb. The average of all cows was 368 lb.

The results of Dairy Herd Improvement Associations have been widely used in extension educational work. News about good practices travels fast, and in every community the practices proved profitable by D.H.I.A. members are soon adopted by others. Although the average production of all cows has increased much less than that of D.H.I.A. herds and many factors besides production testing have come into the picture, it is reasonable to credit the D.H.I.A. program with part of the over-all increase.

D.H.I.A. herds have also been the source of breeding stock for dairy farmers generally. This has been true particularly since the development of the proved-sire program. Proved-sire records have helped greatly to reduce the gamble in selecting a herd sire.

Last, but not least, thousands of dairymen have received production testing benefits through the medium of artificial insemination. Bull studs put a high premium on meritoriously proved sires, and every dairy farmer who breeds his cows artificially profits by it.

Fifty Years of Progress in Dairy Production Teaching

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A half-century of progress in dairy production teaching—how indeed can it be measured? The period from 1906 to 1956 has been one of startling changes in the various fields of science, with greater developments emerging during that half-century than in all previous recorded history. During that period bacteriology, genetics, and endocrinology emerged as full-fledged scientific disciplines, and the developments in the fields of physics, chemistry, physiology, and nutrition are almost beyond belief. Agricultural research in various fields has been no less startling in its developments. Thus the situation has changed greatly by the expansion of scientific knowledge, much of which has had implications for dairy production teaching. As here discussed, dairy production teaching deals with the selection, breeding, feeding, housing, and management of dairy cattle for the economical and sanitary production of milk. Since comparison is one of the most effective methods of high-lighting change, the faculty, courses, curricula, and equipment of one institution, the University of Nebraska, will be discussed as of 1906 and 1956 as a sample of a half-century of change.

H. P. Davis

The Dairy Department in 1906

The staff. In 1906, the Dairy Department was one of five agricultural departments that were a part of the Industrial College, which also included engineering. The staff of the Dairy Department consisted of one professor and one instructor, each with a B.Sc. degree. Although a school of agriculture consisting of a 2-year terminal curriculum was carried on at that period and offered a number of courses in dairying, there were only three courses of collegiate grade offered. Their description follows:

The courses. Course 2. General survey of home dairying—Composition of milk and dairy products. Production, handling, testing, and uses of milk. The creaming of milk by various kinds of centrifugal separators. Ripening, testing and churning cream. Making, scoring, and marketing of butter. The principles of making cheese. Dairy breeding, feeding, and judging. Two hours attendance, three hours laboratory. Two hours credit.

Course 4. Economic dairying—Advanced study in dairy husbandry. Prerequisite: Course 2. Textbook with reading of station bulletins and publications. Two hours attendance. Two hours credit.

Course 6. Dairy Husbandry—Prerequisite: Courses 2 and 4. Advanced studies in experiment station findings. A reading course with one lecture a week. Three hours credit.

There were two optional curricula, as follows:

Subject	General scientific		General agriculture	
	Required	Credits	Required	Credits
Mathematics		10		10
Physics		10		6
Chemistry		10		4
Biological science	12		6	
Zoology		6	either	6
Botany		6		
English	16		16	
Rhetoric plus 3 themes without credit		10		10
English literature		6		6
French or German		10		10
Geology		4		4
Social sciences	18		6	
Political science		6		6
Philosophy		6		
History		6		
Agricultural subjects				30
Electives (could be taken in agriculture)		31		29
Military science		4		4
Total for graduation		125		125

In addition to the courses in dairy husbandry, the other departments offered courses as follows: Animal Husbandry, 7 courses—12 hours credit; Agronomy, 8 courses—12-18 hours credit; Horticulture, 7 courses—9 hours credit; Agricultural Chemistry, 2 courses—4 hours credit. In addition, a course was offered in entomology and one in agricultural engineering.

The staff devoted to teaching agriculture in the Industrial College, not including those listed in the agricultural experiment station, totaled 12 persons and they possessed the following degrees: Ph.D.—3; A.M.—1; Veterinary degree—1; and A.B. or B.Sc.—7. At that time the total enrollment in the Industrial College was 533, but the number taking agriculture is not recorded. It is interesting to note that in 1906 one person is listed as obtaining the A.M. degree with a joint major in agronomy, horticulture and dairy.

Equipment and cattle. A two-story brick building was assigned to the Dairy Department and in it were offices, class rooms, and a large laboratory, which was used for teaching Babcock testing, centrifugal separation, buttermaking and cheese making. In the laboratory were hand testers, barrel churns, wooden workers, and a small cheese vat. A hand milk bottler was used to bottle the milk from the dairy herd and a small churn was used to churn the excess. A short distance away was the dairy barn, a two-story frame building with feed storage above and a silo in the middle. Cows were kept in three rows of stanchions with wooden mangers, cement floors, and gutters. A large room at one end with raised seats on one side provided space for dairy cattle judging. The dairy herd consisted of eight purebred and grade Milking Shorthorns, 24 purebred and grade Holsteins, and 34 purebred and grade Jerseys. Students were used to a considerable extent in feeding, milking, and caring for the cows.

The Dairy Husbandry Department in 1956

The name of the department has been changed, as indicated, and the staff numbers 10 persons, with ranks as follows: professors—6; associate professors—2; instructors—2. The degrees of the staff members are as follows: Ph.D.—6; M.Sc.—3; and B.Sc.—1.

The courses. For freshmen and sophomores there are 14 courses with a total of 31-34 credit hours, of which 6 are general and production courses with 13-14 credit hours. Senior division courses total 7 with 15-18 credit hours, of which four with credits varying from 8 to 10 are in the production field. At the graduate level there are 10 courses listed, of which four are production. Most of the graduate courses have a sliding scale of 1 to 6 credits. All together, general and production courses total 14 with credit varying from 25 to 40 hours.

The agricultural curricula are as follows:

Subject	Technical science		General agriculture	
	Required	Credits	Required	Credits
Mathematics		3		
Chemistry		18		8
Physics		5		5
Biological sciences	17		12	
Botany or zoology		6		6
Bacteriology		3		3
Genetics		3		3
Biological science elective		5		
English		8		8
Social science	12		12	
Economics		6		6
Political science		3		3
Social science elective		3		3
Agricultural subjects	40		40	
Agricultural economics		3		3
Agricultural engineering		3		3
Soils		3		3
Crops		3		3
Feeds and feeding		3		3
Animal science—2 of 3 courses, animal, dairy or poultry husbandry		5		5
Entomology		3		3
Horticulture		3		3
Agricultural elective		14		14
Free electives		21		39
Military science		4		4
		128		128

The other agricultural college departments have expanded through the years to total 14, which include Home Economics, and 314 courses are offered. On the staff of the college, eliminating those serving only on the experiment station, there are 114 persons, as follows: professors, 30; associate professors, 31; assistant professors, 38; instructors, 14; and assistant, 1. On the basis of degrees, the 114 divide as follows: Ph.D.—57; D.V.M.—1; Foreign doctor-

ate— 1; M.Sc.—34; M.A.—11; B.Sc.—6; A.B.—1; and no degree—3. Thus, more than 51% have the doctorate or equivalent and 39% have the master's degree.

Equipment and cattle. For housing the activities of the Dairy Husbandry Department at Nebraska, three different locations are used. The Dairy Research Center consists of a large two-story, brick, T-shaped barn with storage above for hay and grain and stanchions on the ground floor for 96 head of cattle. It is furnished with gutter-cleaning and manure-loading equipment; an ingenious grain handling, processing, and mixing system; and a four-stall milking parlor, where milk flows from the milking machines directly to a cold-wall tank under vacuum. Later, milk is hauled by tank to the college creamery. One small class room is located in the main barn. Other structures at this center are a research barn, a calf barn, bull barn, physiology laboratory, and large two-story structures which can be used for housing cattle, class demonstrations, and dairy cattle judging. Five silos, four upright and one trench, complete the equipment at the main center. Several miles away at an auxiliary center, there are a long two-story open shed, a silo, and other equipment for handling young growing heifers. The present day dairy herd consists of about 160 head of purebred females of the Holstein, Jersey, Guernsey, and Brown Swiss breeds. The females in the herd have made some notably high production records and as a group produce on the average in excess of 400 lb. of fat. Many prizes have been won in the show ring by members of the herd. The Dairy Industry Building houses the offices, library, seminar room, class rooms, and bacteriological, chemical, physiological, and nutrition laboratories. One wing is devoted to dairy manufacturing, and there appropriate modern equipment for pasteurizing, cooling, separating, bottling, and condensing milk and for the manufacture of butter and ice cream and the making and curing of cheese is located. Although no definite estimate is available, considering land, buildings, equipment and cattle, the investment in this dairy department approaches a million dollars.

Course Content Changes in Fifty Years

With the developments that have taken place in all scientific fields, it is to be expected that the contents of dairy production courses differ markedly in 1956 from those taught in 1906. To illustrate some of the changes an example in a few fields will be cited.

Physiology. A half-century ago, the physiology that was taught in dairy production courses dealt largely with the process of digestion. The different sections of the digestive tract were discussed with a brief description of each part and its functions. The physiology of reproduction either was not discussed at all or was treated cursorily in connection with the time of breeding and the length of gestation. Artificial insemination was virtually unknown as a practical procedure before 1938, but now upwards of 25% of the dairy cows in the United States are bred artificially. The result has been that the reproductive processes of cattle are now studied and discussed both in college classes and in extension demonstrations.

Nutrition. In the early part of the century, instruction in feeding was largely confined to an understanding of the feeding standards then in use and to practice in balancing rations for different classes of dairy cattle. Considerable time was spent also in studying rations that had been fed to high-producing cows. Since that time feeding standards have been revised and refined and new ones developed. A whole host of vitamins have been discovered and many of them synthesized. The vital role of minerals in nutrition is beginning to be understood, and hormones, natural and synthetic, as well as antibiotics are assuming an important place in nutritional knowledge. The functioning of that efficient and somewhat mysterious fermentation tank, the rumen, is gradually becoming more clear. Originally only farm-grown feeds and a few of their simpler by-products constituted the sources of nutrients. Now it appears within the realm of possibility that eventually a cow may be fed profitably on a completely synthetic ration.

Milk secretion. At the turn of the century, the theory existed that cows secreted milk at the time of and due to the stimulation of milking and that very little milk was in the udder when milking started. Now it is known that milk secretion is a continuous process carried on from one milking to the next. Fat in the milk was supposed to come wholly from the fat in the feed but now as the result of careful experiments in vitro and with the use of trace radioactive elements it has been demonstrated that carbohydrates and certain organic acids are excellent sources of certain milk fats.

Genetics. The old dictum was to breed the best to the best. A sound principle, still true, if "best" is properly defined. Formerly, cows with exceptionally high records were highly esteemed, and pedigrees were traced through numerous generations to a supposedly great ancestor. Unfortunately, it has been found that a single high production record is not very good evidence of a cow's ability to transmit high production to her offspring. Genetics has pointed out that the milk record is a phenotypic or visible evidence of production and that the genotypic or transmission characteristics are not clearly evidenced by one high record. That does not mean that high-producing cows are not now esteemed, but rather that a series of records, following regular calvings, and without great environmental stimulation are considered a truer index. As a matter of fact, records made on twice-a-day milking for 10 months

are now standard. A good dairy bull is considered to be one that has a group of daughters, preferably not less than ten, which under equal environmental conditions out-produce their dams. Pedigrees are evaluated by studying the production records of the cows (several for each animal are best), together with the daughters' production records for the bulls. Classification scores and show ring winnings are also studied as evidences of conformation. Breeding dairy cattle is not simple and is still to a great extent an art, but genetics has helped in establishing certain fundamental principles.

Disease. Ideas about some cattle diseases in 1906 would now be considered naive, to say the least. For example, contagious or infectious abortion, as the disease was then known instead of the more modern appellation, Bang's disease or brucellosis, was treated by feeding carbolic acid or methylene blue to the cows. As a result, barns containing treated cows were either very smelly or highly colored. That cures were not effected from such treatments is not surprising. Although as yet no cure has been found for this costly disease, vaccination with a mild strain of the infective organism now keeps down the losses and thus has made possible practical control. Garget, now called mastitis, is treated with antibiotics instead of hot packs accompanied with a drench of salts. Milk fever now is known as a calcium deficiency disease and is treated appropriately with the administration of calcium salts, and ketosis, previously often confused with milk fever, is now recognized as an imbalance of carbohydrate and fat metabolism. Thus, the ideas of the causes of diseases have changed as have the treatments recommended.

Management. Early in the century, the ideal housing for dairy cows was considered to be a warm dairy barn equipped with stanchions, gutters, and plenty of windows. What a change today, when for health, convenience, and economy, the loose pen barn or open shed is advocated as adequate and suitable housing for milking cows. Hand milking has all but disappeared in dairy herds of any size, and this and other management practices emphasize the need for conserving labor and reducing the cost of producing milk.

These illustrations give but a hint of the changes that have come about in dairy production teaching and emphasize the impact that scientific research has had upon dairy cattle breeding, feeding, and management.

Curricula and Faculty Changes

A comparison of the curricula of a half-century ago with the present ones shows certain changes. For example, less emphasis is placed upon English instruction, especially in the area of rhetoric. This may be due to better instruction in high school, although college instructors still deplore the poor English of college students. Modern languages and geology have been dropped as requirements, and fewer credits are now required in mathematics. The social science requirements have been lowered, and philosophy has been replaced by a newer discipline, economics. A broadening of the biological sciences has occurred with bacteriology and genetics now taking their place with the older disciplines, zoology and botany. The chemistry requirements have been increased, but perhaps the greatest change has been in the requirements for agricultural subjects. Certain of these are now required and the number of required credits in the agricultural field has greatly increased. Many of these changes have come about because of the tremendous developments in the various fields of science, both pure and applied. Reference to the courses offered in 1906 in agriculture compared with those offered in 1956 will prove that point. The problem now is to choose from the wealth of material available the more fundamental and essential topics for the requirements.

In 1906 dairying as a field of agriculture was relatively new. Instructors at the University of Nebraska had the B.Sc. degree, and there were no graduate courses offered in dairying. Fifty years later the staff has multiplied five times, and 60% have earned the Ph.D. degree and the remainder the M.Sc. with but one exception, who is studying for his doctorate. Thus from 4 years of academic training in 1906, the length of faculty training is approaching 7 years in 1956.

Opportunities for Graduates

Dairy production graduates of 1906 could return to the farm, become herdsmen, or enter college teaching, research, or county agent work. Today the field has widened greatly. A survey at a Midwest institution of animal husbandry graduates indicated that 35% returned to the farm, 24% went into teaching at the high school or college level, research or county agent work, 32% went into some kind of business, usually associated with agriculture, and the remainder were in the armed services or in miscellaneous occupations. Business is the new field which is taking an appreciable group of graduates, and training for it must be considered in planning curricula.

An Evaluation

Any brief discussion of a 50-year span in production teaching must of necessity be based upon only a few illustrations, and in this case one institution, for a complete study of the evolution of production teaching would be a monumental treatise. Certain conclusions seem justified even from this brief presentation. They are as follows:

1. Dairy production teaching now must incorporate scientific developments not only in that field but also in the areas of chem-

istry, bacteriology, genetics, nutrition, and animal pathology, to mention but a few.

2. Curricula for dairy production majors now contain more science, more agricultural courses, and fewer courses in liberal arts but still aim at a broad collegiate training.
3. The academic training of dairy faculties has lengthened.
4. The physical equipment for instruction has increased in extent, variety, and cost.

The past half-century has been a momentous one in scientific development, but there is no indication that the next 50 years will be less fruitful. This outflow of scientific facts has placed a considerable burden upon dairy instructors to digest, evaluate, and incorporate the important facts so that dairy production teaching can keep pace with new developments. Some may look back nostalgically to the good old days when education was more elementary, life was simpler, and the pace of living more leisurely. Those good old days, if in truth they were good, are now gone. Different training and techniques are needed to cope with present-day problems. Perhaps after all we are happier today—who knows?

Research by Federal Agencies on Dairy Manufacturing

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Research on the manufacture of dairy products as a function of the United States Government was first undertaken only a few years prior to the birth of the American Dairy Science Association, the first research bulletin having been published by the Bureau of Animal Industry in 1903. The Dairy Division had been established in the Bureau of Animal Industry on July 1, 1895, and authorized by the Congress "to collect and disseminate information relating to the dairy industry of the United States." That was precisely and exclusively what it did until 1902, when L. A. Rogers became an employee of the Division. There was an "expert in dairy chemistry," G. E. Patrick, working in the Bureau of Chemistry at that time on routine analyses for Henry E. Alvord, chief of the Dairy Division of the Bureau of Animal Industry; this work was being done in connection with efforts of R. E. Pearson, assistant chief of the Division, to make a sterile butter for shipment to England. But except for this work, which was unfruitful, research in the Dairy Division began with Dr. Rogers, whose first publication was on "Canned Butter" and was dated 1904.

E. O. Whittier

The Dairy Division was not permitted for several years to have laboratories of its own in Washington; such research as was done in Washington was in the laboratories of the Biochemic Division. Therefore, when E. H. Webster became chief of the Division in 1904, he was able to carry out his ideas for developing dairy products only by placing men at state experiment stations, where they worked in cooperation with members of the staffs of the stations and often under their supervision. Later, during the period 1909-1920 when B. H. Rawl was chief of the Division, these cooperative arrangements were terminated and the research activities were gradually transferred to Washington.

Cooperative Research Started

The earliest cooperative research was at Madison, Wis., and Geneva, N. Y., where work was conducted on Cheddar cheese; the first bulletin was entitled "The Cold Curing of Cheese," and bore the names of S. M. Babcock and H. L. Russell of the Wisconsin Experiment Station and L. L. Van Slyke, G. A. Smith, and E. B. Hart of the New York Experiment Station. The participation of the Dairy Divsion in the work on which this bulletin was based seems to have been only financial, but later on personnel were assigned to the Wisconsin Station. It was there in 1913 that J. L. Sammis and A. T. Bruhn showed the desirability of making Cheddar cheese from pasteurized milk, a practice that did not come into general use until 30 years later after H. L. Wilson had shown that a slow development of acidity in the cheese vat was needed and could be obtained through proper control of the starter used.

L. A. Rogers and C. E. Gray were assigned in 1903 to the Iowa State Experiment Station at Ames to do research on butter. They spent a winter there while work was being done to provide laboratories and equipment. By spring, the farmers who previously had supplied milk for research at the Station had found other outlets for their milk. So, having to seek facilities elsewhere, Rogers and Gray went to Madison, where they begged the use of the University creamery to make one batch of experimental butter. They then proceeded to Bloomer, Wis., where they set up a laboratory in a tent and carried on their research in conjunction with a cooperative creamery. After a summer at Bloomer and a few months of work at Albert Lea, Minn., they set up a laboratory in the kitchen and woodshed of an old house in Washington near the area now occupied by buildings of the Department of Agriculture and there completed their researches on butter. This was the first dairy products research laboratory in Washington.

FIG. 1. Judging milk at the National Dairy Show in Chicago, 1906. Left to right, L. A. Rogers, W. A. Stocking, C. B. Lane, Ivan C. Weld, C. E. Gray.

The work of Rogers and Gray established the facts that the keeping quality of butter made from pasteurized cream is inversely proportional to the acidity of the cream and that butter can be made from sweet cream. These facts were verified on a large scale in butter made for the United States Navy under the

supervision of the Dairy Division. The general application of these findings resulted in almost complete elimination of fishy, oily, and metallic flavors, which previously had appeared in almost all butter held in storage for appreciable time.

At the Missouri Experiment Station at Columbia, the Dairy Division placed R. H. Shaw with several assistants to work in cooperation with C. H. Eckles on the composition and properties of milk. The publications resulting from this work began to appear in 1911. L. S. Palmer began his work at Columbia under the auspices of the Dairy Division, his first publication on the pigments of milk appearing in 1914.

H. W. Conn of the Connecticut Experiment Station at Storrs proposed about 1902 that he be sent by the Department of Agriculture to France to study Roquefort cheese. Major Alvord did not support this proposition, since he was already planning to do research on Roquefort. Whereupon, Congressional pressure was exerted on Secretary of Agriculture Wilson, who decreed that he would not send anyone to France but would finance cooperative research on the mold-ripened cheeses at Storrs. Three men with salaries paid by the Department were placed at that station. Charles Thom was the mycologist of the group from the Dairy Division, A. W. Dox was the chemist, and K. J. Matheson the cheese technologist. Thom's "Fungi in Cheese Ripening" in 1906 and his classic description of the penicillia in 1909 were important publications resulting from the work at Storrs. Dox was succeeded by J. M. Currie, whose research on the production of citric acid from sugars by the aspergilli was the basis for the commercial development of the mycological production of this acid.

About 1905 an arrangement was made with a cooperative creamery at Albert Lea, Minn., for experimental work on butter and cheese. Although Rogers and Gray made some butter at Albert Lea, most of the research activity there was by C. F. Doane on Swiss cheese. After about 3 years, this cheese research was transferred to Troy, Pa., where it was conducted in connection with a privately owned creamery. The work was terminated prior to 1915, when the creamery was converted into a condensery. Doane was the first to show that a lactobacillus is essential in the making of Swiss cheese and that the use of dry rennet soaked in whey was necessary only because it provided the essential bacteria. As a result of this and related later work, Swiss cheese factories came to use rennet extract and pure cultures. In 1908 Doane published Bulletin 105, "Varieties of Cheese," a publication that has gone through many revisions and is still one of the most popular Government publications relating to dairy products.

About 1915 the business men of Grove City, Pa., were induced to form a stock company to build a creamery according to plans drawn by K. E. Parks of the Dairy Division. This was operated by the Dairy Division as a market milk and milk products plant, making butter, cheese and evaporated milk, and, at times, casein and lactose. Bacteriologists and a chemist were stationed there and did research in a laboratory in the plant. They also participated in semi-plant development of improved manufacturing procedures and new products. The research of G. A. Ramsdell on resazurin as an indicator of the sanitary quality of milk and the work of S. A. Hall on Roquefort cheese were done at Grove City. Soon after 1930, research activities were abandoned at Grove City and similar work was undertaken at the Agricultural Research Center at Beltsville, Md. Thus ended sponsorship by the Department of Agriculture of research in dairy manufactures outside of the Washington area, until it was resumed about 20 years later.

Research Laboratories Established in Washington

The ban on laboratories in Washington for dairy products research had been lifted when B. H. Rawl became chief of the Dairy Division in 1909, and several rooms on the fourth floor of the newly built east wing of the Department of Agriculture building were assigned to the Dairy Research Laboratories of the Dairy Division. These laboratories were under the direction of L. A. Rogers, who, at least in some of his publications at that time, had the title of bacteriological chemist. As cooperative research at the state experiment stations was gradually discontinued, the government-paid workers were transferred to Washington—K. J. Matheson

FIG. 2. L. A. Rogers led the early research work in the Bureau of Dairy Industry and was chief of the Division of Dairy Research Laboratories from 1921 to 1942.

from Storrs, Alice Evans from Madison, and R. H. Shaw and P. A. Wright from Columbia. Other research workers were recruited until nearly the whole fourth floor of the east wing was occupied by personnel working on problems relating to cheese, butter, evaporated and condensed milk, dried milk, ice cream, casein, and lactose. About 1912, research was initiated on the physiology and nutrition of dairy cows. This was under the immediate direction of E. B. Meigs at the Agricultural Research Center, at Beltsville. Since this work is closely related to production rather than to manufacture, its history is not discussed here.

Important accomplishments between 1909 and 1921 include: the finding by H. F. Zoller and O. E. Williams that the sandiness sometimes developing in ice cream is attributable to crystals of lactose; the extensive researches of S. H. Ayers and W. T. Johnson, Jr., on the bacteriology of pasteurized milk, particularly the identification of the bacteria that survive pasteurization; the establishing by J. M. Sherman that the characteristic flavor of Swiss cheese and the "eyes" are the result of the metabolic activities of propionic-acid-producing bacteria; and the researches of W. M. Clark and H. A. Lubs relating to hydrogen-ion concentration. A series of sulfonephthalein indicators for colorimetric determination of hydrogen-ion concentration was synthesized by Lubs. Clark's work on the hydrogen electrode, the hydrogen-ion potential of buffers, and the effects of hydrogen-ion concentration on the multiplication of bacteria, is well known. It is not so well known that he established the conditions for the coagulation and processing of grain-curd casein.

In 1921, C. W. Larson became chief of the Dairy Division, and, in 1924, when the Division became a Bureau, he became the first chief of the Bureau of Dairy Industry. Concurrently, the Dairy Research Laboratories became a Division with Dr. Rogers as its chief. O. E. Reed succeeded C. W. Larson as chief of Bureau in 1928 and continued in the office until the dissolution of the Bureau in 1954. Dr. Rogers retired in 1942 after 40 years of activity in doing and directing the Department's dairy products research.

In the period from 1921 to 1942 was done most of the work of G. E. Holm and G. R. Greenbank on the oxidative deterioration of fats and on conditions for retarding the deterioration of butterfat in dried whole milk. B. H. Webb, R. W. Bell, and coworkers investigated extensively the effects of heat and other processing factors on the viscosity and stability of evaporated milk. Alan Leighton worked on the physical chemistry of ice cream, with special emphasis on its viscosity. He discovered that the addition of cane sugar to skimmilk before concentration caused the concentrated milk to have a low viscosity and permitted the easy separation of lactose crystals. This made possible the production of a low-lactose concentrated or dried skimmilk whereby the proportion of nonfat milk solids in ice cream can be increased without danger of development of sandiness. In the same period L. A. Rogers investigated the factors controlling and limiting bacterial populations; as a by-product of this work, there was developed a commercial process for producing lactic acid by fermentation of whey. W. C. Frazier investigated the proteolytic bacteria of milk and, with E. O. Whittier, the oxidation-reduction potential of cultures of bacteria found in milk. A search for means of killing bacterial spores without the use of a degree of heat producing objectionable color and flavors in milk was begun by H. R. Curran and F. R. Evans in 1930 and is still continuing. Mr. Whittier worked on the ionic equilibria and buffer intensities in milk, with Anne G. Benton on the effects of heat on the H-ion concentration of milk, and with R. W. Bell and S. P. Gould on improvements in the manufacture of commercial casein and on the production of casein fiber. In 1928 the staff of the Dairy Research Laboratories produced the first edition of *Fundamentals of Dairy Science,* and in 1935, a second edition.

In 1939, research on nonfood dairy products was transferred to the regional laboratory in Philadelphia now designated as the Eastern Utilization Research Branch, work on lactic acid derivatives and on casein fiber being continued there. Later, fundamental research on the proteins of milk was undertaken by T. L. McMeekin and his associates, their work on the components of casein and on the individual whey proteins being well known. The recent work of S. R. Hoover and coworkers on the disposal of dairy wastes by biochemical oxidation was done at that laboratory.

G. E. Holm became head of the Dairy Products Research Division of the Bureau of Dairy Industry in 1942 and he continued as head until 1955. Some of the more important research accomplishments of this period were those of T. F. Ford and associates on the deter-

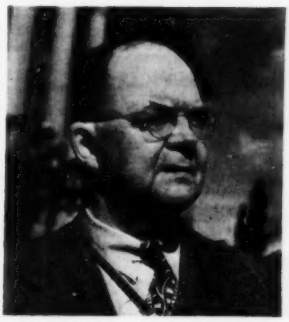

FIG. 3. G. E. Holm (deceased) was head of the Dairy Products Research Division of the Bureau of Dairy Industry from 1942 to 1955.

mination of the particle sizes of the casein-containing colloid of milk and the effects of heat and other factors on the size distribution; the production of a resinous protective coating from lactic acid and the development of a practical lactometer of a high degree of accuracy by P. D. Watson; the production of vitamin B_{12} by means of the propionic fermentation by A. Leviton, the application to cheese of the phosphatase test for efficiency of pasteurization by G. P. Sanders and O. S. Sager; the development of a detergent method for determining fat in dairy products by O. S. Sager; and the development by H. E. Walter and associates of a procedure for making Cheddar cheese in half the customary time.

Research Work Now in Eastern Utilization Research Branch

In February, 1955, the dairy products research activities that began in the Bureau of Animal Industry and continued in the Bureau of Dairy Industry became, after a year of transition in the Washington Utilization Research Branch, a part of the Eastern Utilization Research Branch of the Agricultural Research Service. Thus, all research on manufactured dairy products in the Department of Agriculture was again under one chief, P. A. Wells. The dairy research of the present and immediate future in this organization is concerned with lessening the cost of manufacturing dairy products and with improving their quality. New products from milk that will satisfy new needs and thus increase the utilization of milk are being sought. Research is under way on cheese of several varieties, on butter, and on frozen, concentrated, and dried milks. Special effort is being made to perfect a form of concentrated or dried milk that, even after a year or more in storage, can be readily reconstituted to give a fluid milk having the flavor, consistency, and other characteristics of fresh milk. To supply a sound basis for this work, fundamental research is being done on the desirable and undesirable chemical and physical changes that occur in the processing of dairy products, as in heating, concentrating, drying, storing, and bacterial fermentations.

Again, as in the earlier years, some research on dairy products is being sponsored in state experiment stations, now, however, by research contracts instead of by the informal cooperative arrangements of 40 years ago. Research on Italian-type cheese is being sponsored at the Ohio Station, research on Swiss cheese at the Wisconsin Station, and research on the relationship of salt equilibria in heated milk to its physical stability at the Minnesota Station.

The easy problems in dairy manufacturing have been for the most part solved. This has been accomplished largely in the past 50 years in laboratories in Europe, Canada, the United States, and Australia. The difficult problems remain to challenge us. But with more extensively and intensively trained researchers, with the constantly appearing new research tools and techniques, and with continuing cooperation among federal, university and industrial research laboratories, it can be expected that dairy products research in the United States will in the future, as in the past, make important contributions to the prosperity of the nation and the well-being of its people.

Contributions of Industrial Research in Dairy Manufacturing

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Three technical developments are considered primarily responsible for converting dairy manufacturing from the "cottage" industry of the early 20th century to the highly technical and specialized industry of the present. These are: the invention of the cream separator by the Swedish engineer, De Laval, in 1879; the imparting of keeping-quality to milk by the heat treatment designated as "pasteurization," culminating in the work of the French scientist, Pasteur, in 1864; and a method for rapidly assigning intrinsic value to milk, developed by the American chemist, Babcock, in 1890.

A. H. Johnson

Based on this very practical technological background, experimental work in college and government research stations began to add rapidly to the reservoir of knowledge applicable to dairy problems. Then, as the processing and distribution of dairy products advanced with the growing industrialization of the country, individual engineers and research workers, as well as research laboratories of the commercial dairy industry, began to apply themselves to the technology of milk and its products. The work done by this group is so closely related to that done by researchers in state, college, and government laboratories that in discussing the history of industrial dairy research, it is difficult to distinguish sharply between the contributions of the respective groups. Thus, sometimes the findings of experiment stations or of government workers were passed along to the industry for application; at other times problems encountered by the processing industry were worked on in the industry or referred to more academic organizations for basic research. Also, as the complexity of handling dairy products increased, industry found it necessary to have technical personnel on the staff, at first primarily to test and control operations, but later to conduct original research.

Since milk is by nature a perishable product, it is not surprising that efforts were made from very early times to process it in some way so that it might be used as food long after it had been produced. The making of butter and of butter oil and cheese represents early efforts to impart keeping quality to important milk constituents. There is the well-known story told by Marco Polo of how the soldiers of Kublai Khan in the 13th century carried with them a sun-dried milk. Gradually the products of milk, which have been processed so that they will keep well, have been improved in their palatability and other characteristics. In spite of all the progress that has been made during the past 50 years, further improvement still remains an important problem.

Fluid Milk Industry

Fluid market milk in point of volume is the most important product of the industry. The need for extending the keeping quality of milk was recognized long ago. The treatise of Appert, published in 1804 and entitled "The Art of Preserving Animal and Vegetable Substances," is usually recognized as the pioneer authoritative work. The later work of Pasteur, however, gave great impetus to research in this field. On the introduction of pasteurization into this country between 1895 and 1906, there was strong opposition to it. Hence, from 1906 on, an important development in the dairy industry has been the introduction and extension of pasteurization until now pasteurization of milk is practically a universal requirement. Collaboration between industry and state and federal government research agencies has been especially close in this field.

Exact limits of heat treatment for pasteurization, involving time and temperature relationships for both low-temperature, long-time (145° F. for 30 minutes) and high-temperature, short-time (160° for 17 seconds) were investigated in relation to bacterial destruction, effect on cream line, effect on flavor of the milk, and effects on nutritional and chemical properties of the milk. The contributions of the companies that manufacture dairy equipment and control instruments for pasteurization have been considerable. Engineers of these companies have introduced such economies as regenerative heating and cooling of the milk, use of noncorroding metals, and equipment that can be readily sanitized, just to name a few. The work of the equipment manufacturer has been aided and influenced by suggestions from milk sanitarians and public health officials.

Long ago, mankind observed that milk was good for himself and his children. The findings of state experiment stations and federal government researchers that milk contained several unique nutritional elements served to explain these early observations and to give impetus to the growth of the dairy industry. The work of McCollum on vitamin A, of Osborne and Mendel on the milk proteins, of Goldberger on

the vitamins of the B complex, and the well-known high-calcium content of milk are examples of some important findings.

Intensive investigations on milk also brought to light its inadequacy of vitamin D, especially for children whose sole diet might be milk. Dr. McCollum in 1922 had identified in cod-liver oil the antirachitic factor later designated as vitamin D. The work of Dr. Alfred F. Hess and his coworkers had indicated the prevalence of rickets. On the basis of this work and other findings, the *American Medical Journal* was led to comment editorially in 1932 as follows:

> "Obviously, it ought to be of advantage if antirachitic (vitamin D) properties could be imparted without attending deterioration, in a suitable degree to a few foods that enjoy widespread use, particularly in the dietary of childhood. Milk is of particular interest because of its unrivaled content of calcium and phosphorus . . ."

This situation led the industry in 1932-37 to find ways to increase the vitamin D content of milk. The processes used were: the feeding of high vitamin-D yeast to the cows (developed by Standard Brands), the addition of vitamin-D concentrates to the milk (e.g., the concentrate patented by Zucker), and irradiation of the milk as by the Steenbock process. All of these processes found considerable use at one time. At present, milk is increased in its vitamin D content almost entirely by the addition of a vitamin-D concentrate. As a result of the vitamin-D addition to milk, Jeans wrote in 1947 in his 4th edition of *Infant Nutrition* that rickets had almost disappeared in the country as a whole.

Along with vitamin-D milk has been the parallel development of homogenized milk. In fact, vitamin-D addition and homogenizing treatment are usually accorded the same milk to yield vitamin-D homogenized milk.

The concept of homogenization appears to have been first studied in France as a means of stabilizing oil plus water preparations. Gaulin studied the homogenization phenomena extensively, including milk. Allen in 1904 in an article in the *Scientific American* described homogenized milk. There was much interest in homogenization, and it was applied to dairy products other than milk long before it became generally applied to milk. Homogenized milk was first introduced in Canada in 1927 and did not make its appearance commercially in this country until 1932. Work had been done, in the meantime, on the product both at the University of Illinois and at The Pennsylvania State University and in research laboratories of the industry so that processing problems could be largely eliminated on commercial application. These problems included clarification to eliminate leucocyte sedimentation and proper pasteurization conditions to prevent rancidity development as a result of increased lipase activity on the greater fat surface provided by the homogenization.

By 1940 homogenized milk was well established, and the market for it has continued to grow so that now the percentage of homogenized or vitamin-D homogenized milk produced in individual plants ranges between 10 and 100%. Homogenized milk ranks as one of the most significant developments in the fluid milk industry in this century.

The enzyme, lipase, was mentioned in connection with homogenized milk. The presence of other enzymes in milk was also recognized, and research by public health and other public agencies was conducted to determine whether inactivation of one of these enzymes could be the basis for measuring the effectiveness of pasteurization. Milk diastase and milk phosphatase received the most attention. The work of Kay and coworkers in England eventually pointed out the conditions under which phosphatase activity became a measure of pasteurization efficiency. Many research groups in this country made significant modifications in the test procedures so that it could be adapted to rapid plant tests for determining pasteurization effectiveness. Among these groups were Sanders and Sager, Gilcreas and coworkers, and Scharer. The industry readily accepted the test so that now a phosphatase test adapted to the special dairy product under consideration is routine.

For the first quarter of this century, dairy equipment was largely manufactured from copper or copper alloys. As the technical development of the dairy industry increased, shortcomings of this material became more evident. Corrosion of the equipment, objectionable in itself, was rendered an even more serious problem by the effect that extremely small quantities of copper in the milk had in catalyzing fat oxidation, thereby imparting oxidized or cardboard flavor to the milk or other dairy product. This led Hunziker and coworkers in 1929 to study the suitability of various metals for use in the fabrication of dairy equipment. This work, followed by that of Trebler and Johnson, led the way to the eventual acceptance of stainless steel and nickel chromium alloys as the material of choice for the manufacture of dairy equipment. Thus, research by the dairy industry and by the metal-fabricating industry, in collaboration with experiment stations and government laboratory workers, contributed to the solution of both the corrosion problem and the oxidized-flavor problem in dairy processes. In connection with the oxidized-flavor problem, it is of interest to comment that homogenization markedly reduces the susceptibility of the milk to this flavor defect.

Butter Industry

The origins of buttermaking are lost in antiquity. From such records as are available, it appears that butter was probably first made in

the cooler north-European countries where temperatures were such as to permit the rise of the cream before souring of the milk. Cheese, on the other hand, was mentioned before butter in the warmer climates of Europe.

Buttermaking occupies an important place in the development of the dairy industry in the United States. In 1953, about 23.1% of the milk produced was used for the manufacture of creamery butter, and an additional 3.6% was used in the manufacture of farm butter.

A study of butter production in the United States gives an interesting picture of the changes that have taken place in the dairy industry. Thus, in 1909, 53% of the milk was used for the production of butter, of which 38.7% was factory-made and 61.3% was farm-made. By 1936 the percentage of the total milk used for butter had decreased to 42.27, of which 76% was creamery-made and 24% farm-made. Corresponding figures for 1953 show that 26.7% of the milk was used for butter production with 85% of it produced in creameries and 15% on the farm. Actually, less butter was produced in 1953 than 50 years earlier, the production in 1953 being 1,411,814,000 lb.

Thus, the milk originally used in buttermaking became the reservoir from which the fluid milk industry and other branches of the dairy industry drew its supply as refrigeration and transportation made it possible to bring milk to manufacturing plants and city processing plants.

In the development of the butter industry, federal and state experiment stations and other educational forces and law-making and law-enforcing agencies have had an important part. Much experimental data have been provided by these agencies, and these data have been invaluable in bringing about improvement in the product and in manufacturing methods. In the development of the industry during the past 50 years, the research in the operating industry has been of an engineering or plant research nature, involving improvement in churns and churning methods and various methods of pasteurizing the cream and otherwise improving the cream for buttermaking by various steam- or vacuum-deodorizing procedures.

In 1920 Grindrod introduced the principle of "impact sterilization," which involved the process of injecting high-pressure dry steam into the cream and then releasing the cream into high vacuum. The purpose of the process was to sterilize the cream at lower temperatures than the usual 245° F. for 15 minutes, sterilization occurring by disrupting the living bacterial cells.

The principle of steam injection followed by vacuum treatment has resulted in several patented designs of equipment and processes: the Jensen Super-Deodorizer, the Rogers High Temperature Pasteurizer, the Sealtest Process for Treating Lactic Fluids, the Vacreator Vacuum Pasteurizer and the Volatizer. Incidentally, treatment of milk or cream in such equipment for the purpose of pasteurization also results in removing certain undesirable odors from the product. For example, butter made from cream pasteurized by one of the vacuum-pasteurizer methods (the Vacreator) generally scored higher than the butter made from cream pasteurized by the conventional method.

Another significant development in the butter industry was the perfection of continuous-process buttermaking. This process is particularly advantageous in plants manufacturing large quantities of butter. A number of these continuous-process butter-manufacturing procedures have been invented. Some of these are: the Fritz method, the Alpha Laval method, the Senn method, the New Way method, the C. P. Continuous Buttermaking Process, and the Cherry Burrell–Sugar Creek Continuous Buttermaking Process. These processes differ somewhat in detail but in general involve the preparation and pasteurization of a high-fat phase (e.g., 85% fat), standardization to the composition of butter, and chilling and working to form the finished butter.

Production of plastic cream and of butter oil are really by-products of the research on continuous methods of buttermaking. Plastic cream of 80% fat content is made by passing ordinary cream through the high-speed centrifuge. The patents of North and of Riggs describe methods of making butter oil. The Riggs process involves adjusting the cream to pH 3.8-4.8 and at the same time raising the temperature to 200° F., centrifuging the heated cream to produce an intermediate product of 80-85% fat, maintaining the temperature of this product at 200° F., and diluting with hot water, introducing an emulsion inhibitor, and centrifuging to produce milk fat of 99.5% or higher.

Whipped butter finds considerable market acceptance in some geographical areas. Devices and conditions have been devoloped by which air or other gas, such as nitrogen, can be whipped into the butter to yield a product of the desired specific volume.

Other developments of a mechanical nature include the metal churn (e.g., stainless steel) and the roll-less wooden churn.

As has been indicated, research in the butter industry has dealt primarily with equipment for new methods of pasteurizing the cream and new methods of churning. Many other research findings have been applied to the industry. The original findings have often come from other research agencies, such as state experiment stations, federal research organizations, and public health agencies. The role of the industry has, in these instances, largely been to apply and perhaps carry further the research of the more academic research agencies. Among the research findings to be applied by the industry are: methods of carrying starters; flavor con-

stituents of starters, such as acetylmethylcarbinol and diacetyl; fat-loss problems; implications of cream acidity; significance of vitamin A in butter and its seasonal variation; importance of cream quality; deterioration of butter during storage; oxidative and lypolytic effects on butter quality; and chemical and physical properties of the butter in relation to churning.

Evaporated Milk Industry

The sweetened condensed and evaporated milk industries owe their beginnings to the work of Gail Borden and of John Meyenberg. Since the patents were granted to these pioneers in 1856 and 1884, profound researches have been done on milk as it is affected by processing. This has been particularly true during the last five decades. The research has involved the thermodynamics of condensing in vacuo and different phases of food engineering, bacteriology, chemistry, and physics. Although Gail Borden produced sweetened condensed milk as early as 1856 and it was widely used during the Civil War, evaporated milk was practically unknown to the consumer until the time of the first World War.

Work done by the milk-processing industry and by state and federal research agencies is so closely interrelated that it is difficult to determine accurately the source of the respective research contributions. In the early decades of this century, research by the industry was largely in engineering and equipment design, and basic research on the physics and chemistry of milk was done largely by experiment stations and the federal government. In the last 20 years, however, basic research has been undertaken as diligently by the industry as by other research agencies.

Sweetened condensed milk was a more firmly established product 50 years ago than was evaporated milk. Research in the industry has established methods of manufacture that yield a uniformly fine-textured product by inducing lactose crystallization under controlled conditions of temperature and agitation. Work has also been done to determine the most satisfactory temperatures of preheating and the best conditions for adding the sugar. These are matters of much significance industrially as they determine the body of the final product and the extent to which gelation may occur during storage.

Sucrose is the sugar commonly used in the manufacture of sweetened condensed milk, but research has been done on the substitution of dextrose or corn sweeteners in whole or in part. Dextrose has not found significant use in this industry owing to browning as a result of the protein-sugar reaction.

Evaporated milk became an important dairy product somewhat later than did sweetened condensed milk. Its production has had its own special problems. The Evaporated Milk Association was accordingly organized in 1916, and this Association has played an important role in standardizing the product and in the development of the industry.

One of the objectionable characteristics of evaporated milk during the early years was the leathery fat layer that formed at the surface. Homogenization of the milk assisted materially in solving this problem so that by 1912-14 practically all evaporated milk was homogenized during its manufacture.

Vitamin-D fortification of evaporated milk was practiced as soon as suitable sources of the vitamin became available. Thus, evaporated milk was increased in its vitamin-D content either by addition of concentrates of the vitamin or by ultraviolet irradiation of the milk. This development was of special importance because evaporated milk is so extensively used in infant nutrition.

Other significant developments include improvements in equipment that have resulted in better products and in reduced costs of operation. The multiple-effect vacuum pan, the entrainment separator, and the continuous evaporated milk sterilizer (including preheater, cooker, and cooler) are examples of these developments.

Evaporated milk has become a product in its own right, but research has been continuing to make it more like fresh milk. High-temperature short-time sterilization of the milk with aseptic canning has yielded the most promising results. Improved evaporated milks manufactured by this procedure are now on the market.

A vast amount of basic research has been conducted by industry and by state and federal research groups in an effort to understand the interrelationships of heat, concentration, and pH on the properties of the milk. This work involves the effects of salts, enzymes, casein and serum proteins, sugar-protein reactions, electrophoretic mobilities of casein fractions, and many other physical and chemical phenomena.

Dry Milk Industry

The dry milk industry has had practically its whole commercial development within the last 50 years. Although milk in dry form was mentioned by Marco Polo in the 13th century and later by Appert in 1810, the patents to Gere, to Merrell, to Ekenberg, to Just, to Stauf, and to others during the years between 1897 and 1907 were the basis of the industry that evolved in the next decades. Although there are no federal production records before 1916, it appears that about 2,625,000 lb. of nonfat dry milk and 35,000 lb. of dry whole milk were produced in 1906. Production figures for 1953 are 1,213,000,000 lb. of nonfat dry milk and 104,352,000 lb. of whole milk powder.

Early research sought to improve manufacturing procedures and to make the removal of water from milk an economical process. Hence, in 1913 and 1914 patents were issued to Gray

and Jensen, disclosing a procedure for directing the hot exhaust air from the spray chamber into a spray of milk which operated both to remove dried milk from the air and to evaporate water from the milk. At about the same time the C. E. Rogers Co. began experimenting with the spray-drying of milk and later produced the Rogers Drying Apparatus.

Mojonnier Brothers Co. at first offered an open roll-type drum drier to the industry and later developed the equipment known as the Mojonnier Spray Drying Unit. As there were improvements in spray-drying of milk, so also was roller-drying improved by the introduction of the Just-Hatmaker process, which is still extensively used.

The record of patents issued with their disclosure of inventions is definite evidence of the tremendous amount of work done in the last 50 years by inventors, technical men, researchers, and those actually engaged in the dry milk industry.

. Need for standards for the product and further research for the industry were early recognized. Therefore, in 1925 on the organization of the American Dry Milk Institute, committees for standards and for research assumed responsibility for work in these fields. Industry standards for spray, roller, and vacuum roller powder were shortly forthcoming. The research committee sought to expand the uses for the nonfat milks. Before World War II, uses for nonfat dry milk were primarily in the food industry field. Thus, uses for milk were developed in the following products: bread, sausage, candy, cereal, cake and doughnut mix, and ice cream, with many other products requiring smaller quantities of nonfat milk solids. Work was also done to adapt certain types of milk to the feed industry for supplements to cereal grains for farm animals.

Much of this work was true industry–state experiment station research. Industry grants to experiment stations and other research groups provided the information on which the industry based its growth.

The hygroscopic properties of dried milks made difficult the packaging of the product. The establishment of package specifications for dried milks was accordingly one of the major research efforts. As new packaging materials were developed, they were promptly tested for use with dried milks.

Many of the same research and development findings that were applied to concentrated milks were applied also to dried milks since portions of the manufacturing procedures were the same. These include the use of double-effect vacuum pans, entrainment separators, and milk-heating systems. Applying specifically to spray-drying of milks are types of spray nozzles, centrifugal or pressure atomization, and concentration of milk to be dried.

Recognition of nonfat dry milk as a food of exceptional merit has been the result of years of research. McCollum and others found that milk protein supplemented cereal protein and when used in bread-making yielded bread of superior nutritional value. The baker also found that when milk was used in bread a superior flavor was obtained. The industry, aided by federal research workers, found means of imparting uniform baking properties to nonfat dry milk. Other nutrition workers found nonfat dry milk to be high in calcium and the B-complex vitamins. The industry research groups worked to ensure that milk-processing operations did not impair the fine qualities of the original milk. To remove the stigma attached to its previous designation as dried skimmilk, the name was changed by Act of Congress in 1944 to dry nonfat milk solids. "Dried skimmilk" was retained as the designation for the animal-feed grade of the product.

It was not until after World War II that nonfat dry milk solids began to be used in the home. Recently great impetus was given to home use by the introduction of "instant" products. Instant dispersibility was imparted to nonfat dry milk by a process developed by David Peebles. For this outstanding accomplishment he received the Food Engineering Award in 1955.

Other methods than that used by Peebles for imparting instant dispersing properties to nonfat dry milk have been recently developed. These instant nonfat dry milks are now finding increasing use for household purposes.

Dried whole milk has had a development parallel to that of nonfat dry milk primarily within the last 50 years. The fat content of dried whole milk has, however, introduced important differences in processing and in packaging procedures. The industry learned very early that the butterfat in the dried whole milk was very susceptible to oxidation. Research extending over many years has been conducted to prevent this oxidative change. Although the problem is not yet solved, marked progress has been made. Thus, by preventing completely the taking up of iron, and especially of copper, by the milk; by subjecting the milk to high preheating temperatures; and by packing the dried product in inert atmospheres (e.g., nitrogen), it has been possible to manufacture a very satisfactory dried whole milk.

Until the last war, dried whole milk was not an important product of the dairy industry. Need for milk by the military forces during the war years gave great impetus to research. Industry, state experiment stations, and federal research agencies spurred by the urgent need learned much about the product. Investigations included studies of preheating temperature for the milk, homogenization of the milk, effect of precondensing, promptness of removing the powder from the hot drying chamber, details of nitrogen packing, effects of various antioxidants, effect of fat content, ease of reconstitution, and other variables. Research still pro-

ceeds to make the product more stable during storage and "instant" in its reconstitution properties.

Cheese Industry

Cheese appears to have been made very early in our civilization. Many cheeses are known by the regions in which they originated. Thus, Handbook No. 54 of the U. S. Department of Agriculture describes more than 400 varieties of cheese and lists more than 800 names for these varieties. There are probably only about 18 distinct types or kinds of natural cheese. No two of these are made by the same method; that is, details of setting the milk, cutting, stirring, heating, draining, pressing, salting the curd, and curing the cheese are varied to produce characteristics and qualities peculiar to each type of cheese.

Progress in cheese-making during the last 50 years has largely been due to control of the various steps in the manufacturing process so that uniformity in given desirable characteristics might result. Perhaps the overriding advance that has taken place in this regard is uniformity of the milk used in the process. First, high-quality milk was required from the farms, and second, the milk was subjected to pasteurization.

Good-quality pasteurized milk for cheese-making made it possible to obtain uniformity in production. This was accomplished throughout the various steps of the process by selection of the suitable starters; by control of temperature and humidity; and by uniformity of mechanical handling in the cutting, stirring, and pressing operations.

Uniformity of process and product has been augmented by the establishment of "Standards of Identity for Cheeses, Processed Cheeses, Cheese Foods, Cheese Spreads, and Related Foods," promulgated in 1947 by the Federal Security Agency.

Other products of the cheese industry are the "pasteurized," "processed," or "pasteurized blended" cheese. Cheese of this type has found ready market acceptance as a result of ease in merchandising, uniformity in quality, economy of home use, and excellence in keeping-quality. The manufacture of these products requires the use of materials known as emulsifying agents. The common emulsifying salts are the various sodium phosphates, sodium citrate, sodium tartrate, sodium potassium tartrate, and mixtures of these salts.

Another development of the American cheese industry has been the manufacture of certain cheese foods. Such products are generally known by their trade names, such as Velveeta or Chateau. Velveeta is a cheese food of the pasteurized type and is a blend of American Cheddar cheese, whey solids, and nonfat dry milk. As indicated above, standards for these products have been established by the Federal Security Agency.

It is clear that much progress has been made in the cheese industry during the past 50 years. Little has been said in regard to the specific problems that have occupied the attention of industrial, experiment station, and federal research agencies. Studies have been made on the following problems: mode of action of rennin in cheese-making; clotting and/or proteolytic action of rennin; acid production by starter organisms in relation to the clotting action of rennin; action of enzymes elaborated by starter organisms in proteolysis and lipolysis during cheese-ripening; type of nitrogen compounds formed during ripening; chromatographic studies on amino acids formed and their relation, if any, to cheese flavor; type of starter organisms operating to give full-flavored cheese; effect of homogenizing cheese milk on the ripening of the cheese; use of dry bulk starters in cheese-making; use of proteolytic enzymes alone or with starters to hasten ripening; physical chemistry of casein in relation to cheese-making; nutritional studies on cheese and on cheese foods; and mechanism of emulsifier action in "pasteurized" cheeses or cheese foods.

A perusal of these problems indicates the scope of the work and the fundamental nature of the studies that have been made. A total understanding of the fine structure of cheese-making is certainly far from being realized, but the work goes on.

Ice Cream Industry

It is a far cry from Dolly Madison's kitchen of 1810, where she made ice cream for the statesmen of that day, to the ice cream plant of today. It is a far cry, too, from the early ice cream plants pictured in the Golden Jubilee issue of the *Ice Cream Trade Journal* for June, 1955, to the ice cream plant of today. In this issue Tracy discusses "A Half Century of Progress in Ice Cream Technology." The industry procedures described for making ice cream 50 years ago do not exist at all today although there may be a few ice and salt freezers still in use.

Ice cream mix compositions and mix ingredients have changed substantially during the years. Research has shown the way to better understanding of mix balancing. Use of higher percentages of nonfat dry milk has made it less necessary to use high-fat percentages in order to obtain the desired body. Availability of corn sugar and liquid and dry corn sirups has led to their use in replacing 20 to 30% of the sucrose, thereby, according to some investigators, improving the body of the ice cream. Originally when a stabilizer was used, gelatin was employed. It was not until the early 30's that sodium alginate was introduced, followed by Irish moss extract, locust bean gum, and cellulose gum. Use of these stabilizers eliminated need for aging the ice cream mix, which was common practice with the gelatin stabilizer.

More recently, emulsifiers have been introduced into the mix, and these materials have done much to solve the difficulties of mix whipping. Spans and Tweens and the mono- and diglycerides are examples of the emulsifiers that have found use.

Before it was applied to the fluid industry itself (1916-20), the homogenizer was regularly used in the processing of ice cream mix. Use of this equipment made it possible to obtain the desired overrun more readily and to incorporate butter and other sources of fat more uniformly into the mix composition.

Pasteurization of the mix was also introduced into ice cream processing during the growth of the industry. The most recent development in this field has been the introduction of the Vacreator, already mentioned, and the Roswell heater. Thus, no-hold pasteurization (240° F.) is a reality at this time. This method of pasteurization gives better bacterial destruction, better flavor, superior body effect, and a saving in labor.

Great improvement has also been made in ice cream freezing equipment, from the early salt and ice freezers to the brine and direct expansion ammonia freezers, and finally the Vogt continuous freezer in 1928. Similar freezers developed by other equipment manufacturers appeared a few years later. The introduction of the Vogt continuous freezer and the mechanically refrigerated cabinet (1923) were outstanding events in the development of the ice cream industry.

In the course of time many flavors were added to the vanilla, chocolate, and strawberry of the early days. Specialties also added to growth of the industry, the ice cream cone evolving accidentally to some extent at the St. Louis World's Fair in 1904, and the "Eskimo Pie," a catchword of its day. More recently, variegated ice creams, called "Royale," "Ripple," or "Revel," have been produced by introducing streaks of pure fruit or flavor into the ice cream for added attractiveness.

Soft ice creams, dispensed primarily at roadside stands, are a recent addition to the family of ice cream products. Special mixes are required for the type of freezers used and for the type of product delivered from the freezers. Ice milks with butterfat contents of 3 to 5% are finding increasing popularity in some areas.

"Mellorine" is another recent product of the frozen dessert industry, in which butterfat of regular ice cream is replaced by fat from other sources. This product is not legal in many states.

Research in the laboratories of the ice cream industry has dealt primarily in adapting mix composition and mix characteristics to the rapidly developing equipment used by the industry. Body and texture of ice cream as affected by heat treatment, special processing methods, ingredients such as corn sweeteners, alternate types of dairy ingredients, emulsifiers, stabilizers, nonfat dry milk content in relation to lactose crystallization, and many other special ingredients have been studied. The industry research group has worked not only with the state experiment-station workers on common problems but also with public health officials on problems dealing with pasteurization treatments differing from the conventional ones and on problems of sanitation and microbiological procedure. Perhaps the major technical developments over the last 50 years have been the pasteurization, homogenization, mechanical refrigeration, and the continuous freezer. With these have come the adaptation of the mix composition and mix properties to satisfactory processing.

By-Products

Surplus milk supplies have periodically plagued the industry. During the first quarter of this century and even later, large amounts of skimmilk, buttermilk, and whey were discarded as of no value. Butter and cheese were manufactured from the milk, and these products were considered a means of saving valuable dairy products for future use. As milk stations received larger quantities of milk and as the nutritional value of the milk below the cream came to be recognized, it became worthwhile to convert the so-called by-products of the industry into food and feed products. The dry milk industry was a result of this effort, and accordingly the nonfat part of the milk, as well as buttermilk and whey, was dried. Nonfat dry milk and dried buttermilk have found increasing use in the food industry. Dried whey is still used primarily as a constituent of animal feeds. Just as milk can be converted into heavy-bodied concentrate, so also can buttermilk and whey. Semisolid buttermilk and concentrated whey thus find use in the feed industry for poultry, swine, and calves.

Other by-products also have been developed from skimmilk and whey. Casein is an important product manufactured from skimmilk, but domestic production is much lower than it has been in years past. The whey from casein production, as well as whey from cheese-making, may then be used in the manufacture of lactose, lactic acid and lactates, alcohol, and whey protein or lactalbumin.

At the present time casein production in the United States is about 6,000,000 lb. per year, down from 36,000,000 lb. in 1947. Lower casein production is due to inability to manufacture casein at prices to meet foreign competition, it being more profitable to convert skimmilk surpluses to nonfat milk solids. Most of the casein made in this country is muriatic casein, produced by the Sheffield continuous process. This process has made an important contribution to economical casein production. Casein finds many uses, the most important of which is in paper-coating. The magnitude of total casein usage in the United States at this

time is indicated by 6,000,000 lb. domestic production plus 74,000,000 lb. imported casein.

Production of lactose from whey has also been a research development of the present 50-year era, again an effort to make more complete use of the milk, this time directed to the carbohydrate. Thus, lactose continues to find use for infant foods, penicillin media, and pharmaceutical purposes. Whey has also been subjected to fermentation to produce lactic acid and lactate salts, ethyl alcohol, acetone, butanol, and similar products.

The research on skimmilk and on whey that has been mentioned above had been done largely in laboratories of the industry. Other researches of this nature include development of lactose-hydrolyzing enzymes, delactosing of whey by several types of fermentation, preparation of riboflavin concentrates or adsorbates, acid hydrolysis of lactose, acid and enzymic hydrolyzates of casein and other milk proteins, additional studies on whey utilization, and waste disposal.

Important as applied to milk and whey processing has been the research of experiment stations and government investigators on the solubility and crystallizing characteristics of the various forms of lactose, alpha lactose hydrate, and the alpha and beta anhydrides. The results of this work have been applied to the manufacture of dried milks, dried whey, sweetened condensed milk, and beta lactose of high solubility.

Industrial Research

Industry dairy research as now conducted was practically nonexistent 50 years ago. Individual inventors and observant processors of milk contributed substantially to the then developing dairy science, which was primarily conducted in state and federal experiment stations. Application of results from these research agencies indicated the practicability of research to commercial enterprise. Thus, the research movement, already well under way in the colleges and in other such agencies, gradually established itself in the dairy industry and with special acceleration during the last two to three decades.

At the beginning the research workers were rarely designated as such but were those fortuitously engaged in control, engineering, production, or in other operating functions which gave them contact with the problems of the industry. Then, as the industry became larger and more centralized, and as milk production became more sharply differentiated into processing and distribution, and as processing itself became more specialized into the various branches of the dairy industry, research came to be identified and recognized as a special department of the business.

These developments naturally led to well trained scientists assuming the responsibility for research. Researchers of the several disciplines of science, including chemistry, biology, microbiology, physiology, and engineering, have had prominent roles in dairy industry research. Accordingly, dairy industry research is now conducted in well-equipped laboratories, competently staffed for the areas of their interest.

The problems that have been subjected to investigations by the industry during the last 50 years have already been discussed. In summary, no more need be said except that many of these problems require continuing investigation. With the competence of research groups in industry, as well as in state and federal research stations, and with the research impetus of this era, industry can hopefully expect to learn more about the complicated fluid, milk, and also to develop improved and new dairy products for the consumer and the food industry.

Market Milk Operations, 1906 Versus 1956

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The 50 years since the founding of the American Dairy Science Association has witnessed the growth of the market milk industry from a simple, nearly cottage-type of operation to an industrial factory-type. The market milk industry is not unique in this connection—the automobile, the motion picture, the airplane industry, and many other enterprises have undergone much the same development during the half-century 1906-1956.

J. L. Henderson

Many factors were responsible for the remarkable development of industry in the United States during this period—the growth of cities, research in all branches of science, greater productivity of labor due to scientific discoveries, the development of machines, materials and techniques. Two world wars contributed to the acceleration of research and its application to industrial development. These factors all were important in the changes which occurred in market milk operations during the period.

Market Milk Operations in 1906

Certain discoveries and inventions prior to 1906 made possible the rapid development that started about the time of the founding of the American Dairy Science Association: the Babcock test (1890), centrifugal cream separation (1878), mechanical refrigeration (1834), glass milk bottles (1886), work of Pasteur (1864), tuberculin testing of dairy herds started (1890).

The period 1906-1908 was one of many "firsts" in the market milk industry:

1906—Founding of American Dairy Science Association
1906—First cow testing association
1906—Inspection of country dairies and plants inaugurated in New York
1907—Founding of the American Association of Medical Milk Commissions
1907—Introduction of pasteurization by holding method
1907—U. S. Public Health Service started study of milk and relation to public health
1908—Founding of the Milk Industry Foundation (as International Association of Milk Dealers)

In 1906 the market milk industry was just starting the developments that have resulted in the industry as it now exists. As the above tabulation indicates, the industry had developed to a point in 1906 where it felt the need for united action—to have a means of publishing reports and discussing common problems.

Market milk operations in 1906 consisted essentially as follows:

In the smaller towns and villages, a large percentage of the families kept one or two cows to provide milk, butter, and perhaps cheese. Families that did not keep a cow usually purchased milk from a neighbor who had a surplus. The larger towns were generally supplied by producer-distributors. The cows were kept either in town or a few miles in the country.

The milk "plants" in many of the smaller towns consisted of a milk room where the milk was cooled on a surface cooler. The refrigeration was supplied by well water or by ice. In areas where ice was plentiful in the winter, ice would be cut from lakes and ponds and stored for use in the summer months. After cooling, the milk was filled into cans—3, 5, or 10 gallons or larger sizes. The delivery equipment consisted of a wagon drawn by one or two horses. In 1906 most of the milk was raw and often deliveries were made twice a day because of the poor keeping quality of the milk and lack of refrigeration in the homes. The deliveries were made in the early morning hours. The clank of the steel-clad wheels and horseshoes on cobblestone streets, modified by the noise of rattling cans, was a familiar sound in the early mornings of 1906. In the smaller towns, milk was usually dipped or poured from a bulk can into the consumer's pan, jar, or other receptacle. Although the Thatcher Manufacturing Company introduced the "common sense" milk bottle in 1889, it was not in general use in the smaller towns in 1906; as late as 1910, much milk was still distributed from bulk cans.

The quality of the milk distributed in 1906 was not always good. It was seldom standardized or pasteurized. In periods of milk shortage it was not uncommon to "stretch" the supply with a little water. Little was known about the influence of feed on flavors and nothing was known about the influence of metals on milk flavors. The milkman, as a rule, sold only one product—bulk milk out of a can. He may have sold a little "country butter" of indifferent quality.

In the few larger cities the market milk operations were a little more advanced. The milk-shed was relatively close to the city because of poor quality, lack of good refrigeration, and poor transportation facilities. In many cities an appreciable portion of the milk

supply was derived from dairies within the city limits. By 1906 the large city milk dealer was starting to be a specialist—processing and peddling milk was his principal business. The buildings, processing procedures, and delivery equipment of the larger city milk dealer were somewhat more elaborate than those previously described for the small town producer-distributor.

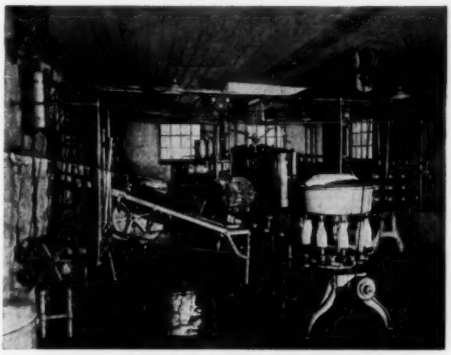

FIG. 1. A milk plant in 1912. Note the Milwaukee "D" filler which was introduced in 1912. Contrast the plant with modern installations shown in figures 3 and 4. (Courtesy of Cherry Burrell Corp.)

Figure 1 illustrates a milk plant of 1912. The equipment is more elaborate than that available in 1906. The Milwaukee "D" filler in the foreground was first manufactured in 1912. In contrast to a 1956 plant (Figures 3 and 4), note the multiplicity of pulleys and belts and the cluttered arrangement of pipe lines. Also note the wooden ceiling with mold growth, the rough masonry walls, and the cement floor. Other features not usually found in modern plants are lack of safety guards on belts, low ceilings, and small windows. The equipment was tinned copper.

By 1906 the large city milk dealer in many instances distributed milk in sealed glass bottles. The bottles were filled by a hand-operated filler that filled a case of bottles at one time. Power fillers and cappers were available in 1913. A primitive soaker-type of bottle washer was available for the larger city plants by 1906 (Figure 2). Most of the city plants, however, at this time used a washer in which bottles were retained in cases. The smaller plants were more likely to use a three-brush bottle washer turned by a steam turbine and later by an electric motor.

Important Factors in the Development of the Market Milk Industry

Many factors were responsible for the changes that resulted in the present market milk industry. Land Grant colleges, the U. S. Department of Agriculture, U. S. Public Health Service, the American Dairy Science Association, trade associations, equipment manufacturers, state and local health departments, and alert operators among producers and distributors all contributed to progress. The growth of cities and the greater productivity of labor accelerated the changes.

FIG. 2. Bottle-washing room of a plant of 1912. Note that 7 men are used in this operation. (Courtesy Creamery Package Mfg. Company.)

Influence of science. The new knowledge of the relationship of microorganisms to disease and the growing awareness of the importance of safe foods to public health were the immediate causes for improvements in market milk operations that started about 1906. Certified milk was developed in 1893, and the regulations adopted pointed out conditions that were necessary to secure a safe milk supply. Standards that were later established for the sanitary production of a safe milk supply were influenced by the requirements of the medical milk commissions for the production and distribution of certified milk. Some of the contributions of certified milk were the double capping of milk, limiting the length of time after production when milk could be sold, refrigeration of the product, checking the health of the cows and employees, the sanitation and cleaning of equipment, and the housekeeping of the premises.

In 1906 the inspection of country dairies was inaugurated in New York. In that year the inspectors were sent into the country with notebooks and cameras to survey the sources of the New York milk supply. The results of the survey made it evident that much work was needed to improve conditions on the farms and in city plants. Ordinances were enacted to improve milk quality. Similar surveys were made in other cities, and by 1914, 77 cities in the United States had adopted ordinances to provide for the sampling and testing of market milk and for the inspection of dairies.

The greatest single impetus to the control of milk quality was started when the U. S. Public Health Service inaugurated a study of the relation of milk to the public health in 1907.

The next year the Public Health and Marine Hospital Service published Bulletin No. 41, entitled "Milk and Its Relation to Public Health." This bulletin was the most complete treatise on the relation of milk to public health that had been published up to that time and it stimulated many improvements in the control of the quality of milk.

The U. S. Public Health Service in 1923, at the request of the state of Alabama, formulated a state-wide milk control program. A standard milk ordinance was promulgated as a result of the work of the U. S. Public Health Service and Alabama officials. The ordinance was printed in 1924. Since that date it has been revised many times. *The Standard Milk Ordinance and Code* recommended by the U. S. Public Health Service has done more to influence the thinking of milk sanitarians and to establish uniformity in milk legislation than any other document. By 1955 the ordinance had been recommended for use by 34 states and two territories; it was adopted state-wide in 11 states and two territories, by 1,594 municipalities and 419 counties. It is estimated that 60,000,000 people live in areas covered by the ordinance and code.

The Land-Grant college dairy husbandry and dairy manufacturing departments played important roles in the development of the market milk industry. Their research, teaching and extension activities gave a technical basis for the industry and supplied personnel qualified to carry the information to milk plants and dairy farms. The graduates became owners, managers, superintendents, and quality control personnel of milk plants; fieldmen, inspectors, and health department sanitarians.

Influence of knowledge of nutrition. The discovery of vitamin A by Dr. E. V. McCollum in 1913, and his work which demonstrated its importance to the health of mankind, marked the beginning of scientific interest in milk as a superior food. The knowledge that milk was a good source of vitamin A stimulated research on the other nutritional factors in milk. Later work with respect to vitamin D, the water-soluble vitamins, milk proteins, and minerals further established the importance of milk in nutrition. The experiments of Dr. H. C. Sherman on the nutritional factors required to achieve "buoyant" health dramatically illustrated the benefits of drinking milk regularly in adequate amounts.

The National Dairy Council program brought the nutritional benefits of milk to the attention of doctors, dentists, nurses, nutritionists, and teachers. The program for serving milk in schools, which was initiated in 1924 by the National Dairy Council, made possible the educational program that secured the aid of doctors, dentists, and other professional groups interested in the health and well-being of children.

The medical profession has long regarded milk as the logical food to receive vitamin D fortification. A large percentage of homogenized milk is now fortified with vitamin D concentrates. In 1932 the vitamin D potency of milk was increased by either the feeding of irradiated yeast to cows or by the treatment of milk by ultra-violet radiation. Later fortification of milk consisted of the addition of vitamins A and D to nonfat milk, the addition of vitamins A and D and certain of the water-soluble vitamins to whole milk, and the addition of iron and/or iodine.

Influence of industry associations. The Milk Industry Foundation, founded in 1908 as the International Association of Milk Dealers, has played an important part in bringing about events that resulted in the present market milk industry. In 1909 the first convention proceedings were published. Two of the papers presented illustrate the development of the industry at that time. Dr. H. L. Russell of the University of Wisconsin spoke on the subject "Difficulties in Enforcing Ordinances Requiring Cows to be Tuberculin Tested." B. H. Rawl, Chief of the Dairy Division, Bureau of Animal Industry, presented a paper entitled "How to Gain the Cooperation of the Producers in the Endeavor for Better Milk." In 1920, when the Association had about 70 members, the first full-time secretary, R. E. Little, was hired. Programs started in the early twenties resulted in an accounting manual, a sales manual (1929), a laboratory manual (1933), and a plant manual (1949). The manuals, the annual meetings, and the published proceedings have assisted in progress in all phases of market milk operations and industry progress. In 1956 approximately 1,000 milk dealers were members of the Foundation.

The Dairy Industry Supply Association, founded in 1912 under another name, has also contributed to the development of the market milk industry. In 1920 the Association established the first industry-wide fair practice code. Major contributions of the D.I.S.A. include the sponsoring of the Dairy Industries Exposition, the establishing of the 3A sanitary code standard in cooperation with the Milk Industry Foundation and the International Association of Milk and Food Sanitarians, the sponsoring of collegiate judging in cooperation with the American Dairy Science Association, and the establishing of grants for research. The market milk industry has benefited by having so many groups working to improve quality and reduce costs.

Another industry agency that has helped the market milk industry to advance is the National Dairy Council, which was founded April 24, 1915. In the early years the Council provided leadership along lines unifying the thinking on dairy industry programs, which influenced sound legislation and combated animal disease. Through later programs of advertising and education, the Dairy Council spread infor-

mation so that people would get to know and appreciate the full value of dairy products.

In 1918 five state-wide dairy councils were organized and affiliated with the National Council. This trend has continued and as of December 31, 1955, 71 dairy councils have been organized in 35 states. In addition there are 11 branch offices and one Greater New York National Dairy Council Program. The program is thus operating in 83 markets covering 35 states.

The International Association of Milk and Food Sanitarians, the American Dairy Association, and the Dairy Industry Committee are other organizations whose personnel, funds, and talents have been used to make the market milk industry of 1956 one of the most progressive in the United States. The effective advertising programs of the American Dairy Association and the National and Local Dairy Councils should result in increased use of dairy products including fluid milk.

Changes in Milk Production

The developments and improvements in milk production for fluid consumption have aided the changes and progress of market milk operations. In 1906 tuberculosis was a common disease of cattle. Herds were first tested in 1890, but even by 1906 testing was not a common practice. The cause of infectious abortion was not known. Tuberculosis, Bang's disease, and mastitis reduced dairy production and were responsible for much human sickness. Today tuberculosis among dairy herds is not widespread, and much has been done to eradicate Bang's disease. Mastitis still remains a serious problem in many areas.

In 1906 the first cow-testing association began operation. The cow-testing program, including culling of poor producers and feeding according to production, increased milk production per cow. The use of proven sires and artificial insemination techniques has further increased the potential milk production capacity of dairy cows.

Cows with greater milk production, mechanization of operations by the use of milking machines, mechanical refrigeration, and improved farm machinery have made milk production per man-hour more economical and have assisted in making milk one of the most economical of foods.

Programs to produce milk with good flavor by controlling feeding, the health of cows, and elimination of corrodible metals in equipment have made a milk supply that in most cases is more acceptable to customers.

Transportation. When the milk-producing farms were close to the city, the problem of transportation was simple; the dairyman hauled his cans to the plant with horse and wagon. Along with the cities, the milk-shed expanded and the problem became more important. The first development was direct shipment in baggage cars. Then followed in 1872 the establishment of the first receiving stations, where milk was assembled in the country, cooled, canned, and shipped as car-lots in baggage cars. Later, special refrigeration cars were used and, finally, tank cars. The first tank car shipment of milk was made from Bellows Falls, Vt., to Boston in 1903 in steel tanks lined with enamel and mounted in a refrigerator car.

As highways improved and as automotive engineering advanced, truck and tank-trucks became the most widely used conveyors. In 1916, 98% of the milk going to New York City was shipped by railroad; by 1934 this percentage had decreased to 63, and by 1938, 53% was shipped by truck. In many markets, 100% of the milk has been a direct haul since about 1934. The direct shipment of milk increased as the direct haul areas expanded. As tank trucks improved in performance and capacity, the direct haul areas made it possible to consolidate or abandon many receiving stations. The bulk handling of milk at the farm has made possible the wider use of direct shipment in tank trucks. A modern tank truck and trailer can haul up to 6,000 gal. of milk. Tank trucks are now used to haul milk from midwest areas to eastern and southern states.

Pasteurization. Pasteurization has been the most important processing factor that permitted the market milk industry to become a factory-type operation. Pasteurization of milk, as first practiced in Germany by Dr. Soxhlet in 1886 and a little later in the United States by Nathan Strauss in New York, consisted of boiling rather than heating to a lower temperature for a definite time. The milk was used for infant feeding and distributed through milk depots (1893).

According to Charles E. North, the first flash milk heater used in the United States was imported from Denmark in 1895. Pasteurization, when first practiced by milk dealers in the United States, was carried out secretly as a means of preserving milk. In 1906 the New York City Board of Health prohibited secret pasteurization. Pasteurization methods have undergone changes as scientific information on thermal death points of bacteria and the effect of heat on properties of milk became available and as equipment and controls were improved. The first method was flash pasteurization, by which milk was heated momentarily to 160°F. or above and held for 30 to 60 seconds. Work of Russell and Hastings (1900) and Rosenau (1912) established that 140°F. for 20 minutes effectively destroyed *Micrococcus tuberculosis* and other pathogens. This work resulted in the second method of pasteurization. This method was the holding process, which, when first established, was 145°F. for 30 minutes. After 1920 many ordinances permitted 142°F. for 30 minutes. In the 1939 edition of the *U. S. Public Health Service Milk Ordinance and Code,* the

minimum was raised to 143°F. for 30 minutes. Many systems and types of equipment were developed for pasteurizing milk by the holding method. Refinements were made in equipment to insure that every drop of milk was heated at the specified temperature for the specified time.

The third step in the development of pasteurization procedures was the in-the-bottle pasteurization. This development occurred in the period 1910 to about 1917. Another variation in this process was the bottling of hot pasteurized milk. This type of process, however, did not fit in with large-scale operations and did not become generally established. The second method of pasteurization, the holding method, remained the approved system for pasteurization until the fourth method appeared, namely, the high-temperature short-time (HTST) system. The precursor of the HTST system was the Electropure Process, or the treatment of milk by electricity. The lethal effect on bacteria resulted from the temperature to which the milk was heated rather than from the electric current.

The introduction of the Electropure equipment stimulated research on the lethal effect of various time-temperature combinations on the causative organisms of diseases that could be carried by milk. Research indicated that 160°F. for 15 seconds destroyed pathogenic organisms when they were present in milk. The present form of the plate-type of HTST equipment was rapidly developed during the period 1927-1933. The usual procedure was to heat the milk to 161°F. for 16 seconds. In present operations it is usual to increase the temperature of homogenized milk to 163°-165°F. Automatic control devices for the HTST system and the phosphatase test have made the process reliable and have given the health authorities a test for proper pasteurization. The HTST system has been an important factor in simplifying market milk processing and has made continuous operations possible. In many milk plants all fluid products are processed by the HTST system.

In most areas of the United States, all of the milk is pasteurized. Pasteurization has given the milk dealers a safe milk to distribute to their customers.

Homogenization. The homogenizer was developed in France and patented in 1892. Various other devices for accomplishing subdivision of fat globules were developed in later years. Homogenized milk was distributed in Belgium and France before 1927. Apparently the first homogenization of market milk on a commercial scale on the North American continent started in Ottawa, Canada, in 1927. By 1935 a few distributors in Michigan, Illinois, Ohio, and Virginia were selling homogenized milk.

The introduction of paper containers, the increase in store sales, and the increase in vitamin D milk, especially fortification by adding concentrates, stimulated the extension of homogenization. In many markets, 80% or more of the milk sold is homogenized, and many distributors homogenize 100% of their milk.

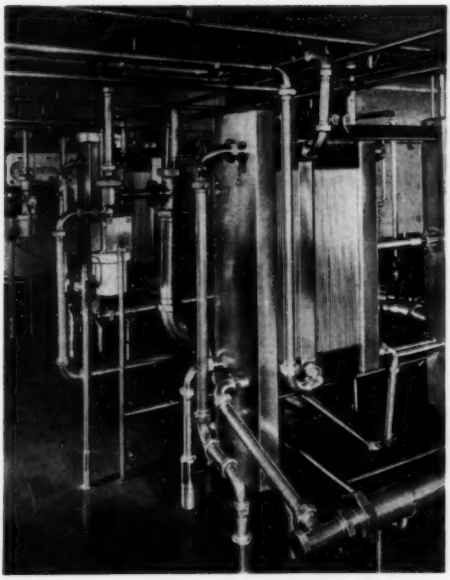

FIG. 3. Modern HTST installation. Note construction of floor, walls, and ceiling, and control panel in back wall. (Courtesy of Creamery Package Mfg. Company.)

Containers. The changes and improvements in milk containers have played an important role in the evolution of the market milk industry. The glass milk bottle was invented by Thatcher in 1886. For many years glass bottles were made in a conventional form that differed little from the "common sense" bottle of 1889. General use of bottles was brought about by development of machinery for washing, filling, and capping and by the extension of legislation which required the pasteurization of milk. Between 1910 and 1920, the regulations of milk supplies to insure safety of milk including provisions that required that milk be sold in sealed bottles resulted in practically universal use of the glass milk bottle as a container for milk.

Changes in glass bottles between 1920 and 1950 were made to reduce breakage and weight, to use less space, and to permit the use of smaller caps. The changes have resulted in the present light-weight square bottle with a small cap. Amber bottles are used to reduce the effect of sunlight on milk flavor and vitamins, especially riboflavin and ascorbic acid. The half-gallon glass bottle and the gallon jug have come into greater use since 1945.

FIG. 4. Modern filling equipment for half-gallon bottles. (Courtesy of Creamery Package Mfg. Co.)

The paper milk bottle was invented in 1906. Since then many types have been developed. The industry, however, showed little interest until the new types currently available were developed. The increase in the use of paper containers has been rapid since 1935. By 1940, 4.8% of bottled milk was sold in paper containers. The proportion had increased to 30.6% by 1950 and to 54% by 1955. The increase in use of paper containers accompanied the increase in the sale of store milk. In recent years there has been an increase in delivery of retail milk in paper containers. Where paper containers are used 100% on retail milk routes, it is usually more successful when most of the dealers in the area adopt this type of container.

Distribution Changes

As described earlier in this article, distribution of milk in 1906 was largely of two types—from bulk cans in small towns and in glass bottles in larger towns and cities. Horses and wagons were used almost exclusively; milk delivery was almost exclusively a retail operation. Milk was delivered either once or twice a day—if only once, it was delivered in the early hours of the morning. In 1906 most of the milk was raw. The interest in public health and milk quality, which started about this same time, resulted in state laws and city ordinances that gradually required that all milk be distributed in sealed containers, and many ordinances required that it be pasteurized.

With the improvements in the automobile, dealers began to purchase trucks for outlying routes. The change to trucks was gradual, and as late as 1952, horses were used in a few eastern cities. Milk was delivered to customers every day until the start of World War II. The necessity for saving gasoline and tires and trucks brought about every-other-day delivery (E.O.D. delivery). Since 1950 the six-day delivery system, serving each retail customer three times a week, with no Sunday delivery, has been adopted in a number of milk markets.

Market Milk Operations, 1956

The market milk industry of 1956 comprises approximately 15,000 dealers and utilizes approximately 55% of the total milk supply. The developments described since 1906 have resulted in an industry that provides the population with a safe, convenient milk supply at a reasonable price. The milk now processed in market milk plants comes from dairy farms that operate under the supervision of local and state health departments and the dealers' field and quality control departments. The customer can have confidence in most areas that the milk is produced by healthy cows maintained in a clean environment. In many milk sheds, most of the milk is picked up by tank trucks from bulk farm tanks. Milk from receiving stations likewise is now usually shipped in tank cars or tank trucks.

Processing in milk plants in 1956 generally occurs in sanitary, well constructed, and well equipped plants. Practically all of the equipment, including pipe lines, storage tanks, and HTST units, is of stainless steel. Milk is generally clarified, standardized, pasteurized, homogenized, and fortified with vitamin D. Approximately 45% of the milk is bottled in glass and 55% in paper. Milk is usually delivered on retail routes every other day or three times a week. Wholesale delivery to stores, except to smaller stops, is every day. The retail routes usually handle 400 to 600 units a day, and wholesale, 1,500 to 3,000 units. The large plants in the biggest cities generally operate 6 or 7 days a week. Plants in medium-sized towns often process only 5 days a week. The large city milk plants usually supply distributing depots in outlying suburbs or nearby towns. The depots in turn operate retail and wholesale routes in their adjacent areas.

The milk plant of 1956 produces many products that were not available in 1906: Vitamin D-fortified milk, nonfat milk fortified with vitamins A and D and also frequently with additional milk-solids-not-fat, sour cream, chocolate drink, orange juice, orangeade, cultured buttermilk, half and half, yogurt, pressurized cream, eggs, and ice cream. In contrast to the plant of 1906, the modern milk plant is designed to make sanitation and good housekeeping procedures convenient. Most milk-processing plants are provided with a quality control laboratory equipped to evaluate the quality of

the raw milk received and the finished products distributed.

Future Developments

The necessity for increasing the output per employee will dictate the future development of the industry. There will be fewer and larger milk processing plants. HTST pasteurizing units will have a larger capacity. Bottle filling and capping equipment will operate at faster rates. Automatic casers and case stackers will speed up delivery of milk to the cold storage room or dock conveyor at a lower labor cost. More plants will operate on a 5-day week. Bulk tank pickup will become more prevalent, and this among other factors will result in larger dairy farms and fewer of them. Receiving stations will decrease in number and importance. The truck hauler will become an important link between the dairy farmer and the milk dealer. He must be trained to judge the flavor of the milk at the farm before it is loaded into the tanker. He will become an important aid to the field department in his contacts with the producer.

The can-washing function at the city plant will be confined to house cans, cans for bulk milk, and dispenser cans. The receiving deck will be simplified and will provide facilities for unloading tank trucks into milk storage tanks. Several tankers may be unloaded at one time in large plants, thus eliminating the long line of trucks with cans of milk waiting to unload.

Automation, the automatic control of a complete process from start to finish, will become important in the operation of market milk plants. Continuous processing of liquid products is especially adapted to automation. In-place cleaning will receive the first attention—cleaning will become a push-button operation. Later the flow of milk from the storage tank to the cooler will be a push-button operation.

An important problem in the industry will continue to be the methods of cutting the cost of delivery. This problem will result in the continued trend toward the sale of more milk in paper containers through stores. Pricing methods must be found to make retail delivery attractive to large users of milk. Discounts for more units delivered per stop is one way to hold retail sales and reduce the cost of delivery. More product per stop can be influenced by a reduction in the number of times a week the customer is serviced. Many are now served three times a week—perhaps the next step is twice a week. Houshold refrigerators of large capacity are becoming more common, and the better keeping quality of milk will permit fewer deliveries. The use of milk dispensers in restaurants, hotels, and other eating establishments will grow. Vending machines for quarts and half-gallons will doubtless become more important in milk distribution.

Other forms of milk will become available for supplementing or displacing some of the fluid milk business. The 3-to-1 milk concentrate sold in paper in some stores may at a later date be more widely used. Instant nonfat dry milk solids and perhaps an instant powdered whole milk will doubtless in the future become a substantial supplement of fluid milk supplies. Canned sterilized whole milk and aseptically sterilized concentrated milk have been developed on a commercial scale and, under favorable price conditions, can be expected to expand in use. Frozen 3-to-1 concentrate in paper may become a standard item in home freezers, especially on farms. Milk made by recombining low-heat nonfat milk powder and butter oil may find a market in certain areas in the United States.

The increasing interest in nutrition and weight control will doubtless result in increased sales of vitamin A and D fortified nonfat milk and in multi-vitamin fortification of whole milk.

Homogenization will become nearly universal—in many markets it is already 80% of the supply. This should result in increased sales of half and half and table cream.

Butter Manufacture

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"As we look backward, let us look forward"
—Charles Penrose

"The roads you travel so briskly lead out of dim antiquity, and you study the past chiefly because of its bearing on the living present, and its promise for the future."
— Lieutenant General James G. Harbord

These quotations shall set the pattern of this discussion. It is neither desirable nor practical to discuss periodical history without reference to the past, nor to disregard completely its impact on the future. Butter has had a long and interesting history. It is one of the oldest manufactured dairy products, if not the oldest. Earliest records indicate its usage in religious rites more than 4,000 years ago by Hindus and East Indians. During the eras of Hippocrates (460-357 B.C.), Dioscorides (1st century A.D.), and Sidonius Apollinaris (428-484 A.D.) butter was used for medicinal purposes, as a remedy for sore eyes, or as a dressing for burns and wounds of man and beast. The last usage has continued down through the centuries, as records will show, and reports were current during World War II of the use of melted butter in Russian field hospitals for the treatment of severe abdominal wounds.

L. C. Thomsen

Industrially, its use was described by Pliny (23-79 A.D.), Plutarch (50-130 A.D.), Galen (131-201 A.D.), and Clement of Alexandria (150-220 A.D.) as a hair dressing, a body cream, in baths, as a dressing for leather, and for use as an oil in lamps. As late as the last century, it was used in combination with pine tar as an ointment for Scottish sheep in order to improve the quality of their wool.

Since its usage for food even in ancient times was taken for granted, references with respect to this are not common. The best known Biblical references can be found in Genesis 18:8 . . . "And he took butter and milk . . ." and in Proverbs 30:33 . . . "Surely the churning of milk bringeth forth butter." Both Alexander the Great (356-323 B.C.) and the Emperor Augustus (63 B.C.–14 A.D.) provided their troops with some butter. Its scarcity, or the fact that it was highly prized as a food, occasionally resulted in high prices. At the time of the Emperor Diocletian (284-305 A.D.) it sold for $3.59 per pound in terms of the amount of silver present in an American dollar. Venentius Fortunati (530-609 A.D.), Bishop of Poitiers, complained of its high cost. As an article of international commerce, it was known to both the Phoenicians and the Norwegians prior to 1,000 A.D.

Early History of Commercial Buttermaking

Although there was some duplication in the developments during the periods that marked the ancient, medieval, and modern history of butter, most of this concerned merely the methods that were used for producing butter from milk and cream. Dasher type churns were in use by the Hindus long before the Christian era. The number of patents granted by the U. S. Patent office on churns during the first 70 or 80 years of the past century averaged one for every 10 or 12 days. From 1890 to 1940 there was no noticeable change in this rate, but there appears to be a slight decline at present.

There is evidence of at least a slight duplication in one other field. Pliny is said to have indicated that water and milk were best when boiled. It may be assumed, therefore, that some butter was made from "pasteurized" milk more than 1,900 years ago.

If a date were to be selected to mark the historical advent of modern butter manufacturing, 1856 would probably receive a majority of the votes, for that year marked the beginning of the factory system of buttermaking. It is indeed noteworthy that the centennial of the establishment of a creamery at Campbell Hall, Orange County, N. Y., coincides with the Golden Jubilee of the American Dairy Science Association.

The 50 years immediately after 1856 were indeed remarkable years for the butter industry. So many of the prototypes of machines now used in the butter industry were developed during this period that it does not appear astonishing for Mr. Harry Hayward, Assistant Chief of the Dairy Division, Bureau of Animal Industry, USDA, to include in his annual report for 1903 the statement: "Butter was taken out of the realm of empirical arts and placed on a scientific basis."

During the 50 years a galaxy (with apologies to the Greek derivation of the word) of developments and inventions resulted in almost phenomenal growth of the creamery industry. From an output of less than one million pounds of factory butter in the entire United States in 1856, one creamery (Franklin County Creamery, St. Albans, Vt.) was producing butter at the rate of 20,000 to 22,000 lb. daily in 1895. At the turn of the century there were more than

7,500 creameries in operation, making over 400,000,000 lb. of butter per year. It was estimated that the total factory and farmer output of butter in 1899 required the milk of 11,000,000 cows (almost one-half of the current cow population) and that at least 7,000,000 people—10% of the population—directly or indirectly earned their livelihood from the butter industry. The value of the butter sold per year was equivalent to 5% of the entire value of the total agricultural output. In 1890 the factory system had barely penetrated beyond the Mississippi river —the first creamery west of the Mississippi river had been established in Iowa in 1871—but by 1899 Iowa had become the leading butter producing state with a factory output of 88,000,000 lb. plus a farm output of 50,000,000 lb.

Kansas boasted the largest creamery in the world. But, even so, more than two-thirds of all butter produced in the United States was made on farms. Sixty million pounds of renovated butter were produced per year with at least 75 factories engaged in this type of operation. The U. S. consumer was using butter at the rate of 20 lb. per capita per year. This was equivalent to 2% of the entire food supply, or 19.7% of the total food fat requirements. This indicates the general progress which was made from 1856 to 1906, but a host of specific inventions or developments made this progress possible.

Linde in Germany and Boyle of the United States had produced the first commercially successful ammonia compression refrigeration machine in 1873-1875. The first successful centrifugal power cream separators were introduced between 1877 and 1879. Practical centrifugal hand separators first appeared in 1886, but by 1899 there were 40,000 in use. The first cooperative creamery in the United States was established at Luck, Wis., in 1887 (one had been in existence in Denmark since 1882). The Babcock test was developed in 1890 and the Gerber test in 1892. Significantly, they measured to a high degree of commercial accuracy only the fat that was present in milk or cream. The development of the right type of bacterial cultures about 1890 made possible the production of butter with controlled flavor. Technical developments such as these inevitably led to the establishment of dairy schools for the purpose of carrying on research and instruction in dairy industry. The first such school in the U.S.A., dedicated wholly to these activities, was established at the University of Wisconsin in 1889.

Some of the hardships of factory buttermaking were eliminated by the development of combined churns and workers in 1892. The conversion of the Franklin County Creamery at St. Albans, Vt., in 1895 to a "centralized" type of operation with more than 50 skimming stations marked the beginning of the "centralizer" system of buttermaking. This turned out to be one of the greatest factors in establishing the creamery industry in all sections of the United States. It attained its maximum importance about 1923. Pasteurization was introduced commercially to the American butter industry by the University of Wisconsin in 1896. On a commercial scale, pasteurization of cream for buttermaking was first carried out at Albert Lea, Minn.

As early as 1863, leaders in the industry recognized the value of organized efforts, and the American Dairymen's Association was formed. State associations began to be organized in 1870. Journals devoted more or less to the creamery industry also came into being about this time. By 1890, most of the butter was still made from sour cream and churned at an acidity of 0.50 to 0.70%. A lower acidity was regarded as responsible for the lack of flavor in butter. It was believed that in addition to exposure to light or to alternate freezing and thawing of milk or cream, a tallowy flavor in butter could be due to the consumption by the cows of tallowy tasting meal or of an excess of young green clover in the diet.

The butter buyer was already insisting that "the consistency of butter should be such that when placed upon the table it could be easily spread." The butter score card was in existence in exactly the same form as found today. Three cents was considered a fair margin for making and marketing a pound of butter.

Such were the conditions when the Official Dairy Instructors' Association (presently the American Dairy Science Association) was organized in 1906. It is of interest to note that of the membership roster of 1907 and 1908, 15% could be identified directly with the butter industry. If the same ratio were to hold with the present membership, at least 250 persons would have to acknowledge butter as their major interest.

History of the Industry Since 1906

The main events and developments prior to the organization of the Official Dairy Instructors' Association have been discussed in some detail. It is therefore fitting that a similar approach be taken to developments and events in the butter industry for the period of 1906 to 1956.

Shortly after 1906, Iowa State College applied scientific principles to the manufacture of "neutralized" cream butter. Although it was known as early as 1900 that good butter could be made from pasteurized sweet cream, this practice was not favorably regarded until after 1912, and particularly during and after World War I. Whereas considerable quantities of butter had been made from factory skimmed milk prior to 1906, by 1923 nearly all of the creamery butter produced in the United States was from farm separated cream. One of the main reasons for this change can be attributed to the increase in the size of creameries and their inability to contend with the large quantities of

foam produced by factory separation of milk. Scientists and equipment engineers directed their attention to this difficulty. After first developing foam destroying machinery, the problem was eventually solved by the invention of foamless type separators about 1933. Fortunately these machines had reached such a near state of perfection at the time of World War II that the tremendous demand for nonfat dry milk solids could be readily satisfied.

The enthusiasm of the creamery operator for the manufacture of pasteurized sweet cream butter was not shared completely by all consumers and butter buyers, many of whom had been accustomed to butter with more flavor. Again, scientists began to look for simpler and less costly methods than the use of bacterial cultures. The result was first the introduction of synthetic flavoring compounds in 1933, and shortly thereafter (1935), the development of distillates prepared from desirable butter cultures by dairy scientists at the University of Illinois.

Newer knowledge of metallurgy made possible greatly improved pasteurizing and cooling equipment, thus reducing the incidence of off-flavors resulting from the presence of copper and iron salts in the cream and butter. It also made possible the development of all-metal churns. It has been stated that the first churning of butter in an all-metal churn was made in Los Angeles, Calif., on October 27, 1932.

Movable workers were first used in churns in 1893, but the first modern roll-less churn was not built until 1931. The continuous system of buttermaking had been a dream of scientists and dairy equipment engineers for many years, and patent literature on the subject goes back to the time of the invention of centrifugal separators. Neverthless it did not become a practical reality until the time of World War II.

Important changes have taken place in the method as well as the type of pasteurizing equipment for creamery operation. Some of these have had as their objective the elimination of defects traceable to the quality of the milk or cream reaching the factory. In this category may be found the vacuum type machines. Others were developed to increase the efficiency of operations.

During the past 50 years the butter industry has not been without its controversial economic problems. Chief among these were rationing, price control, and farm subsidies during part of World War II, and more recently various price support programs. On the other hand, there have been economic developments that have been given almost universal approval. The most outstanding of these has been the American Dairy Association, which was founded in 1938 and which has as its major objective increasing the sale of dairy products, although it also sponsors research on dairy products.

The improvement of the quality of butter has been, and still is, of major concern to the creamery industry. As early as 1904 some dairy schools, such as Pennsylvania and Wisconsin, were carrying on monthly educational butter audits, including such services as quality grading, composition analysis, and eventually bacteria, yeast, and mold counts. Cream grading was first initiated in 1905. The passage of the Federal Food, Drug and Cosmetic Act of June 25, 1938, was one of the most important events in the history of quality improvement in butter, much as it was for other food products.

As the over-all knowledge of butter manufacturing developed, it was natural for scientists to devote their energies to more specific problems. A survey of the investigations on butter and related subjects reported in the *Journal of Dairy Science* since its first publication in May, 1917, should serve to envision the problems confronting the industry at various periods, as well as to indicate the progress that has been made in solving them. Approximately 469 original articles pertaining directly or indirectly to butter have been published in the Journal in its 39-year existence. A listing, by subjects, of such articles, on the basis of their importance, as judged by numbers of papers, has been arranged in Table 1 by ten-volume periods. Such arrangements tend to indicate the degree of interests as well as the shifts that have occurred. Many of the changes in interest are the result of developments in scientific knowledge.

This table serves to indicate the direction in which research in the butter industry is moving. It may serve as a guide for shaping new research because it also indicates fields in which members might increase their activities.

Credit should be extended also to those members who for one reason or another preferred, or felt compelled, to report their findings through some other medium than the *Journal of Dairy Science*. Such research is not included in the tabulations in Table 1. Credit is likewise due the popular magazines and the various associations for the splendid job which they are doing to bring the findings of research to the men in industry.

The Industry Today and 50 Years Ago

As the curtain descends on the fiftieth anniversary year of the American Dairy Science Association, it would seem desirable to reexamine the butter industry of today as it compares with that of years ago.

The population of the United States has more than doubled. The cow population is only slightly greater than it was in 1906. Production per cow has doubled. The amount of farm-made butter has declined from slightly less than one billion pounds to an all-time low of 211,000,000 lb. The total butter output is about the same. Consumption per capita per year has dropped from 20 lb. to less than 10 lb. Butterfat, percentage-wise, now supplies less of the total fat in the diet than it did in 1906. Roughly, nearly

TABLE 1

Classification of 469 original papers appearing in the Journal of Dairy Science, *Vol. I to Vol. XXXVIII, No. 11, inclusive, relating directly or indirectly to butter, arranged in the order of the number per subject*

Subject	Volumes I to X incl.	XI to XX incl.	XXI to XXX incl.	XXXI to XXXVIII incl.	Total all vols.
Oxidation and antioxidants	4	3	29	19	55
Analytical methods; butter, milk, cream	7	2	22	16	47
Cultures and ripening	3	6	9	19	37
Lipases; rancidity	1	2	11	20	34
Vitamins; nutrition	–	6	20	8	34
Molds and yeasts	9	6	11	1	27
General quality; grading	6	3	10	4	23
Bacteria	1	9	6	6	22
Cleaning; sanitation	–	4	5	12	21
Feeds: effect on flavor and composition	–	2	10	–	12
Physical properties; structure	3	1	7	1	12
Acidity of cream and butter	2	1	7	1	11
Churning	–	7	1	3	11
Composition and composition control	1	4	1	3	9
Phospholipids	–	5	3	1	9
Frozen cream	–	3	5	–	8
Metals	–	6	2	–	8
Buttermilk	1	5	1	–	7
Iodine number	–	5	1	–	7
Phosphatase	–	–	2	5	7
Butter oil and ghee	1	1	1	3	6
Care of milk and cream	–	1	1	4	6
Flavors	1	–	3	–	4
Losses	2	–	2	–	4
Methylene blue and resazurin tests	–	3	1	–	4
Pasteurization	2	–	1	1	4
Sulfhydryls and sulfides	–	–	3	1	4
Tocopherols	–	–	–	4	4
Water insoluble and volatile fatty acids	–	–	–	4	4
Globulin; waste disposal; committee report (one each)	–	–	–	3	3
Neutralization	2	–	1	–	3
Salt	1	1	1	–	3
Air in butter; butter wash water (one each)	–	2	–	–	2
Carbonated butter	2	–	–	–	2
History	1	–	1	–	2
Management	–	2	–	–	2
pH	–	2	–	–	2
Reducing systems	–	–	1	1	2
Sediment	–	1	–	1	2
Total solids	–	–	2	–	2
Emulsion	1	–	–	–	1
Glycerides	–	–	1	–	1
Oleomargarine	–	1	–	–	1
TOTAL	52	88	181	148	469

one-half of all creamery butter now made in the United States comes from factory-skimmed cream.

As the American Dairy Science Association stands upon the threshold of the next 50 years, it is fitting to survey the objectives that it has set for itself with respect to the butter industry. For this survey, free use has been made of the report by the American Dairy Science Committee on butter, which was presented at the June, 1954, meeting at Pennsylvania State University, and which appeared in Vol. XXXVII, No. 5, p. 590.

This report stated in part: "Creameries should manufacture butter of uniform composition, high quality, attractive color, and excellent keeping quality." The report goes on to say that this should be brought about by:

Uniform state laws governing minimum sanitary standards

Industry sponsored quality payments

Intensification of educational quality programs

Educational butter scoring and analytical services

Short courses in butter manufacturing

Granting certificates of proficiency to deserving buttermakers
Adoption of uniform inspection services
Research on improved methods of manufacturing as they are related to *(a)* bacterial growth, *(b)* enzymatic activity, *(c)* chemical catalyzers, and *(d)* exposure to odors
Research on the improvement of body, texture, and spreadability
Inducing buttermakers to apply improved techniques
Ascertaining consumer preferences

The committee suggested furthermore that an attempt should be made to determine the long-range problems of the butter industry in order to formulate long-range policies and to establish farsighted research projects. More investigation along economic lines should be initiated in manufacturing, packaging, and storage so as to keep prices within reach of the consumer. Efforts should be made toward more utilization of creamery by-products. Some of the projects suggested are now in progress.

Additional research on nutrition and continuation of research now well under way dealing with rapid and practical methods for detecting the presence of competitive fats in butter and dairy products should be encouraged.

At present butter accounts for approximately one-fourth of all the fat produced in milk, and it promises to continue as the main outlet for surplus milk for a long time to come.

Cheese Manufacture

WALTER V. PRICE
Department of Dairy and Food Industries, University of Wisconsin, Madison

Many changes have been made in the cheese industry during the past 50 years. The location of the factories, the type of buildings, the equipment, the methods, and even the finished products are different. In this discussion of these changes, names of people have been associated with some events, but more often they have been omitted. Photographs are shown only of men who have made history—not those who are making it today. Scientists may be disappointed that this narrative emphasizes changes in the art, but such has been the history of cheese manufacture.

W. V. Price

Areas of Manufacture

In the early 1900's production centered in the north central and north Atlantic areas (see Table 1). It then moved west and south in the United States as the annual production increased from 300,000,000 to over 1,300,000,000 lb.

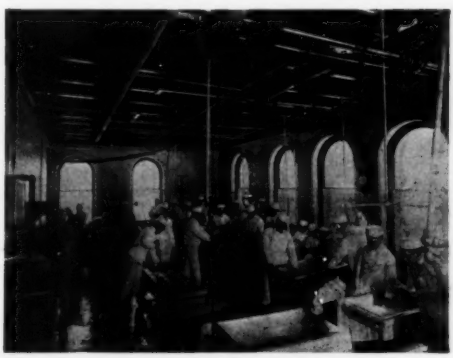
Training of the Early Cheese Maker

The making of cheese in 1906 was an art which men learned by practice under a skilled master. The young apprentice, often the maker's son, started his career by learning to scrub the wooden followers and to nail canvas on their edges, to line the hoops, dress the cheese, and gather wood for the self-heating vat. During the winter the young beginner sometimes attended a dairy school or university short course to learn how to separate the fat from whey and to run the Babcock test. The instructors who did research, wrote texts, and trained the students have had an important influence in shaping the lives of thousands of young men during the past 50 years. Today, industry depends more on in-plant training for preparing factory workers and on universities to supply men with the necessary technical knowledge.

In the early period some states required of cheese makers only a license to perform the Babcock test. In 1915 Wisconsin adopted the licensing of makers, factories, and corporations operating factories to assure proper training of cheese makers and more adequate supervision of factories and methods of manufacture.

Cheese makers have accepted unions slowly, but one was formed in Wisconsin in 1907. Makers in Oregon's Tillamook Valley set up a "union" but dropped the name when farmers objected. Wages and working conditions were usually set by personal bargaining powers. Eventually, labor unions were accepted, but only in some of the larger operations.

A few women have been cheese makers and operators of factories. Linda Bruhn operated a factory at Auburndale, Wis., as early as 1912. For many years she was the well-known secretary of the cheese makers' association in central Wisconsin. Wives of cheese makers, especially in one-man factories, commonly assisted their husbands in making, packaging,



Cheddar cheese laboratory, Cornell Dairy School about 1910.

TABLE 1
Manufacture of cheese in the United States, not including skimmilk varieties

Area	1909	1919	1929	1939	1949	1954
	(million lb.)					
United States	311.1	473.6	483.9	708.5	1,200.0	1,383.1
N. Atlantic	119.4	110.3	57.8	69.6	103.1	123.2
N. Central	182.6	333.3	363.5	513.6	899.6	1,031.1
S. Atlantic	[a]	0.2	1.4	1.1	2.2	3.9
S. Central	[a]	[a]	14.2	55.6	114.7	130.1
Western	8.2	28.7	46.9	68.5	80.4	94.9

[a] Too small to report.

and plant clean-up. In both world wars women replaced many men in factories.

Formation of Trade Associations

Like the early guilds of the old country, associations of cheese makers acted to educate and protect the interests of their members. The Wisconsin Cheese Makers' Association is probably the oldest active group. It started in the early 90's, and its members today take an active part in considering industrial problems and legislative matters affecting the industry. In 1921 R. B. Stoltz helped organize an association of manufacturers and dealers to publicize cheese. In 1927 the National Cheese Institute was organized to represent its members in legislative matters, public relations, and promotional and research work.

Some associations included both manufacturers and farmers, like the Wisconsin Swiss and Limburger Cheese Producers' Association; others, like the American Producers of Italian Cheese, represented a segment of the industry.

Factory Facilities

In 1906 factories were usually built of wood, and the maker's home was often located on the second floor. Curing rooms were sometimes cooled with sub-earth ventilating ducts or with ice chambers; rooms for curing were sometimes dug into a hillside or located on the north side of the building. Cement floors and cement drains were beginning to replace wooden floors.

Cheddar cheese factory of 1915.
(by Marschall Dairy Laboratory, Inc.)

Self-heating or flue-type vats were common, but replacements were being made with steam-jacketed, 5,000-lb. vats. Curd racks, blade curd knives, wooden rakes, and wooden followers for hoops were normal equipment. Centrifugal whey separators were not common although they were available. Milk was delivered in 20- to 30-gal. cans and hoisted into the factory by a hand winch. Idealists believed that the factory should have the equipment needed for the Babcock test, the acidity determination, and the Wisconsin curd test. A steam-bath sterilizer and glass jars for starter also were deemed essential. A 2-vat factory was regarded as most

Cheddar cheese factory of 1920.
(by Marschall Dairy Laboratory, Inc.)

efficient, and an intake of 15,000 lb. per day was considered large.

By 1910 cheese manufacturing showed signs of greater mechanization. Improved vats were available; wire curd knives were being introduced; continuous presses were preferred over the upright type. By 1915 curd racks were seldom used, and the 10-gal. can was seen in some but not in all factories. One man could handle up to 8,000 lb. of milk a day.

In the 20's better roads simplified hauling problems and helped develop larger factories. A Swiss plant at Antigo, Wis., was receiving 48,000 lb. of milk per day. About this time a new holder-type, pasteurizing cheese vat and improved mechanical agitators were introduced.

In the 1930's the electric motor increased labor efficiency. Coal stokers and gas and oil burners reduced boiler room work. Mechanical refrigerators and can washers were placed in many factories. Wide curd knives and curd-forking agitators became common.

The 1940's ended the period of low-cost equipment for cheese making. The well-equipped plant had to have a can washer, pasteurizer, filter or clarifier, and mechanical refrigeration. Stainless steel was used extensively. Holding tanks in factories were of greater capacity and efficiency. Regenerative type, continuous pasteurizers were adopted rapidly in this decade.

Progressive makers of 50 years ago visualized some of the features of modern factories, but they could not foresee their size nor their dependence on modern transportation. Equipment and facilities like separators, clarifiers, pasteurizers, can washers, pumps for milk, whey and curd, power machinery, pallets, re-

Modern cheese factory.
(by Kraft Foods Company)

frigeration, and control laboratories have been improved or developed since 1906. Today factory construction emphasizes sanitation by means of tile walls and floors, improved lighting, plumbing, and heating, and waste disposal without stream pollution.

Factory Operation

Fifty years ago cheese factories usually closed in winter; today it is not uncommon to find factories making cheese every day in the year and both day and night during the busy season.

Payments for milk were largely on the pooling basis 50 years ago although the Babcock test was being adopted rapidly. Factories in New York were first to experience the competition of the fluid milk market. In the 20's some of them began to make cheese only in the flush period and at other times acted as receiving stations or as producers of soft unripened cheese. Today large factories in the eastern states produce cottage and cream cheese, sour cream, and similar fermented milk products throughout the year. Stand-by factories produce Cheddar cheese for a few weeks in summer. Flexibility of operation and production of special brands and types of cheese characterize the industry in fluid milk areas. Identical trends of factory operations are increasingly obvious in the north central region today.

Regimentation of the cheese industry during World War II showed the greater economic strength of the large plants. Control of prices and cheese production encouraged large dealers to buy or lease factories. About half of Wisconsin's factories were so operated at the end of the war but these leases were generally ended in 1947.

Mergers of plants have been accomplished successfully in Wisconsin, Minnesota, and Oregon. The Tillamook Cheese Association with its diversified operations at Tillamook, Oregon, and its effective sales organization is nationally known.

Trends in numbers of Wisconsin factories indicate the impact of forces affecting their economic welfare. Starting with 1,518 factories in 1905, they increased to 2,807 in 1922. Since 1922 about 50 per year have stopped making cheese, and the total in 1954 was down to 1,077. But the factories remaining in 1954 produced five times as much cheese as was made in 1922. Eighty-three Wisconsin factories produced 28% of Wisconsin's 547,000,000 lb. in 1952. Annual production per factory in 1905 averaged 72,000 lb. whereas in 1954 it was 565,000 lb.

In 1906 the separation of whey cream for butter making was being introduced. Swiss operators had actually skimmed cream for butter by hand; American makers had used the fat on the whey tank for soap making and for greasing cheese. The skimmed whey was used for stock feed. The problem of returning whey to farms has discouraged direct feeding in recent years in some areas, and whey has been sold to centralizing plants for condensing or drying for human food or stock feed. Other industrial uses of whey constituents for manufacturing or fermentation are generally of interest in specialized plants rather than in cheese factories, although there are some exceptions.

Factory Inspection of Milk

In 1906 the quality of milk was judged by its odor and appearance. Cheese makers were learning to use the Wisconsin curd test. General use of the sediment test began around 1910. The methylene blue test was not applied to milk for cheese until the 30's. Morning's milk was commonly delivered uncooled, and until Swiss was made only once each day, all milk for that cheese was delivered without cooling.

In better factories today milk is inspected by such tests as methylene blue, resazurin, sediment, and temperature. Minimum standards in some areas make these tests compulsory. The Wisconsin curd test may be used today in emergencies. Farm inspections are necessary in some areas to make certain that conditions of milk production meet legal standards. Fieldmen who are employed by single factories or groups of factories have been effective agents for quality control since World War II.

Filtration of Milk

In early days, a piece of cheesecloth over a rack was used to strain the milk into the vat. In the late 30's filters were made for factory use.

Centrifugal clarification of milk for cheese attracted attention in the early 1900's. Babcock tried it then, and in 1913, when better machines were available, the procedure was found to be even more effective. Later work in factories and laboratories showed measurable improvement in Cheddar cheese manufacture but the process is still not widely used. Swiss cheese operators accepted clarification almost univer-

A. T. Bruhn
Cheese Maker

W. W. Fisk
Author

sally in the 20's because it resulted in better eye formation and higher grades.

In the 1940's manufacturers were required to guarantee their cheese as acceptable for interstate shipments. Tests for extraneous matter in cheese were developed and applied for inspection and control purposes. Careful examination of incoming milk, milk filtration, protection of make room and factory from insect and rodent pests, and other precautionary measures quickly became routine operations in well managed factories.

Standardization

Adjustment of fat or solids-not-fat in milk for whole milk cheese was not legal in most states in 1906. Wisconsin officials protested the practice in the making of Swiss cheese but lost the case in court in the 20's. Makers of other varieties in Wisconsin promptly adopted the procedure despite the protests of buyers. The Wisconsin legislature in 1929 outlawed the process for Cheddar, Brick, Munster, and Limburger, but allowed it for Swiss, Italian, and some minor varieties. Federal definitions of 1950 permitting adjustments were copied in most areas, including Wisconsin.

J. L. Sammis
Dairy Chemist

H. H. Dean
Investigator

In the meantime, standardization of milk for Swiss cheese had gone on enthusiastically—if not wisely. Factory studies in Wisconsin in the 30's showed that makers had to allow 2% above the minimum fat in the dry matter in order to avoid the risk of substandard cheese. Operators conformed.

Pasteurization

From 1900 to 1910 the possibility of using heated milk for cheese interested the industry. Danes and Germans were flash-heating milk to about 180° F. for skimmilk cheese. Some Americans tried these treatments without success. However, trials continued and by 1909 the industry had heard of the Wisconsin experiments with pasteurized-acidified milk.

By 1923 editorial opinion began to favor pasteurization for health protection and industrial development. Reports from New Zealand were encouraging. Lower heat treatments used at Cornell were giving better results. The holder method produced slightly better quality of cheese than flash heating but the flash method fitted better into plant operations. Flash heating to 155°-165° F. was commonly used in the 30's in the newly developing areas of the south central states.

Compulsory pasteurization had been suggested before 1940. A typhoid epidemic in California caused that state to pass a law requiring pasteurization of milk and either processing of the cheese or holding it for at least 60 days at curing temperatures before offering it for sale. Eventually these three safeguards were adopted by several states and incorporated in federal definitions for practically all varieties of cheese.

In Wisconsin many operators and dealers vigorously opposed pasteurization for many years. State and federal extension workers demonstrated procedures in individual factories. Manufacturers of equipment were strong advocates. The general use of heat treatments by large cheese producers was a very convincing argument. Specific instructions for making cheese were published in Wisconsin in 1944 and later by the U. S. Department of Agriculture. These bulletins were widely distributed in all parts of the country. Surveys showed that 80% of the total U. S. cheese production could be made from pasteurized milk in 1948-49, whereas in 1944 only 51% could be so produced. The greatest gain was in Wisconsin.

Acidity in Cheese Making

Acidity in cheese making was commonly estimated 50 years ago by observing speed of rennet action and by the hot-iron test. The new titration test for acidity was being accepted readily. All three tests are still used in modern factories but the titration test is favored.

In the early 30's measurement of pH in cheese making and curing came into limited use. Systematic making procedures have been perfected by using pH measurements in conjunction with other tests to regulate acid development and control the finished cheese.

Cheese makers have always held milk at or near the setting temperature to develop acid. Improvements in this practice began with the use of better starters in the early 1900's. Lactic starters were being introduced rapidly in 1906; at least six companies were selling them. Use of held-over whey and sour buttermilk did not stop, but by 1910 three-fifths of the exhibitors at the monthly scorings in Wisconsin's Dairy School were using commercial cultures.

From the beginning of starter practices, dairy schools taught the techniques of aseptic handling and management of the cultures. Practical makers were very slow to abandon the idea of the "held-over" starter. Unfortunately careless starter making and management

is not uncommon in factories today. In better factories the starter commands the most careful attention, the best possible facilities, and the most skillful technicians.

H. L. Russell and E. G. Hastings in Babcock Memorial Garden

Heat-loving starters for making Swiss cheese were not unknown to makers at the turn of the century. The effects were usually obtained by incubating whey or whey containing portions of blown, dried rennets, which were usually imported. The pure culture program of the U. S. Department of Agriculture eventually gave cheese makers a greater control of acid development. Later the eye-forming, flavor-producing culture was isolated and introduced.

The use of cultures other than lactics for flavor in Cheddar cheese has attracted the interest of bacteriologists since the use of heated milk began. Numerous microorganisms have been tried but none is generally used in culture form on a commercial scale. *Streptococcus faecalis* apparently has approached this goal most closely.

Troubles with slow starters have become increasingly common since 1940. Bacteriophage has been responsible in some instances. Methods of meeting such situations have been widely studied and taught to industry. Whitehead of New Zealand pioneered the use of single strain cultures and their rotation to stop phage build-up. Sanitation control and the rotation of commercial lactic starters are being practiced. Antibiotics used to treat inflamed udders have contaminated milk and caused serious, unpredictable failures in cheese making. Makers have tried to inform farmer patrons of the problem but have had only limited success.

Cheese makers know that calcium chloride acts in milk like acid to hasten rennet action and to firm curd; it is used today for those purposes, as it was in 1900.

Curd-Making Methods

The granular stirred-curd process was still being used for Cheddar 50 years ago, but the matting or cheddaring system was rapidly supplanting it. By 1920 it was rarely used except in emergencies and for making Pineapple cheese. Then during World War II the process was advocated to save labor by substituting machine-forking for the hand-stirring method of earlier days. The process revived briefly. It probably inspired some recent changes in heating, salting, and pressing the granular curd that have been tried on the factory scale in this country and in Australia. These methods may be the beginning of a new system of making Cheddar cheese.

L. L. Van Slyke
Research Director

E. L. Aderhold
Cheese Judge

The intermediate stage between the old granular process and the matted curd of today was the procedure of draining curd on a rack. Here it was stirred or allowed to mat as the condition of the curd required. Eventually it was found that the curd at dipping could be drained in the cheese vat, and by 1920 very few makers were following the old procedures. Some veteran makers feel that perhaps the new, less laborious methods have failed to keep something of the distinctive qualities of the old-time cheese.

The soaking of milled curd in water at 50° F. was patented in 1906. A storm of argument followed: Traditional cheese makers warned of poor keeping quality and abnormal composition; some dealers refused to buy cheese made in this manner; others bought and sold it at

E. C. Damrow
Inventor

H. L. Russell
Scientist

premium prices. Soaked-curd cheese was introduced into Wisconsin in the early 20's. It has now been defined and standards of composition have been set by regulatory officials. It is a popular modification of Cheddar cheese in certain markets. Colby cheese, made by a cold water treatment of the granular curd, is widely used in the north central states to satisfy markets similar to those that accept the soaked-curd cheese.

Treatments of Cheddar curd with hot water became common in Wisconsin in the 1920's. The treatments were said to produce closer texture, reduce moisture, and control abnormal fermentations. They also removed considerable fat from curd. Effects of the hot water varied with the temperature and amount of water and the duration of the treatment. Some makers actually heated the curd to pasteurizing temperatures to control early gas defects. The practice is still followed with numerous modifications.

Matting curd in a modern Cheddar cheese factory. (by Kraft Foods Company)

The broad aspects of the ecology of cheese making contrast sharply with attempts of research workers during the past 50 years to identify specific microorganisms, enzymes, or groups of such biological agents to hasten development of the characteristics of cured Cheddar cheese. From these studies has emerged the present concept that cheese flavor is a balanced blend of many contributing flavorful substances, such as volatile acids, amines, amino acids, diacetyl, esters, ketones, and aldehydes. But the development of these products in Cheddar cheese is directed, as it always has been, according to the nature of the milk supply and the practice of the maker's art.

Applications of eye-forming, flavor-producing culture for Swiss cheese and of mold cultures for Camembert and mold-veined cheese are well established in cheese making practices. The limited use in industry of some selected organisms and enzyme preparations for curing effects may indicate that similar ripening agents or treatments for other varieties of cheese may not be remote.

The major contribution of the past 50 years to biological control of cheese curing has been the perfection, for commercial use, of lactic starters—the low-temperature lactics for Cheddar and high-temperature lactics for Swiss and related types. These organisms, as used in modern factories, establish desirable conditions in curd making for all subsequent curing changes.

Paraffining

Paraffining was being used to some extent for Cheddar and Brick cheese about 1900. By 1907 the practice was firmly established as a method of reducing shrinkage and protecting quality. Flexible wax was introduced to the cheese industry in the 1930's. Other modifications of paraffin are now available to give this coating better flexibility, adhesive properties, and crush resistance. Small units of cheese of any kind when covered with wax are now readily accepted in all markets.

Styles

Cheddars, Flats, Daisies, Young Americas, and Longhorns were well known to the trade in the early 1900's. Five-pound loaves of paraffined Cheddar with clean, straight edges and uniform weight were offered in boxes and cartons in the 20's and tended to displace the Young Americas. One-pound prints were tried but did not sell well. Prints weighing 2 and 2½ lb. were popular in the 30's, and in 1952 a Wisconsin manufacturer was moving 30,000 2-lb. midget Longhorns per week.

In 1941 the 20-lb. and 40-lb. blocks became basic styles of the modern, natural cheese prepackaging program. A few manufacturers regularly make mammoth styles weighing ½ to 3 tons. Probably the largest cheese ever made weighed 31,964 lb.; it was pressed on a freight car at Appleton, Wis., in 1919. These huge styles are made for exhibition and advertising.

Boxes

In 1913 paper boxes came into use for packaging cheese. Makers and dealers soon indicated that they preferred boxes made of wood for cheese to be held. After World War II fiber boxes again appeared in greatly improved form and materials. These are now used widely for the block styles of cheese.

Wooden boxes are still most commonly used. The round, veneer boxes of today are lighter in construction than the first boxes. Special crates had to be used to protect them for overseas shipment during the last war. Square boxes for wrapped cheese are carefully made

and finished to exact dimensions. They keep each block of cheese in perfect shape to cut by machine into pieces of uniform size that are suitable for mechanical wrapping operations. These boxes make possible and practical the modern program of prepackaging cheese for retail distribution.

Prepackaged Cheese

Manufacturers have tried for many years to supply retail stores with a rindless package of cheese of guaranteed weight and quality. Cheddar cheese, sealed in cans, was cured in Oregon in 1904. Canning on a small scale and consumer testing continued intermittently in laboratories and industry until World War I. At that time Camembert and Swiss were reaching the consumer in cans on a commercial scale.

In the 1930's gas-venting valves in special cans were developed. Test packs were made in Pennsylvania, Oregon, Washington, Wisconsin, and Minnesota. Canning of sliced Cheddar and Swiss cheese was tried in Idaho and Ohio. In one year a 200,000-lb. pack of Cheddar was put up in 5-lb. and 12-oz. tins by one Wisconsin company. For that pack the Cheddar cheese was pressed in special hoops and delivered daily to the warehouse for analysis, grading, and canning. Several commercial canning operations were ended by the material shortages of World War II. Cheese is being cured under vacuum in sealed cans at Washington State college in a successful pilot plant operation.

The possibility of using films, foils, or other wrappers to protect rindless cheese was attracting attention in the 20's. The example of packages of process cheese was a powerful incentive to manufacturers and merchandisers of natural cheese. The first commercial package covered with cellophane and wax was patented by C. M. Gere in 1933. Tinfoil-wrapped prints of cheese were merchandised in 1924; the foil was applied under heat and pressure. Several films of the many that were tried are now available for commercial use. Each film or wrapper has its own special properties which determine how it must be used in wrapping, boxing, curing, and merchandising; each has its advantages and limitations. Most of these films are applied to blocks of Cheddar cheese weighing 20 or 40 lb. Since the wrappers are applied soon after pressing, only the factory-making record and the curd itself show what quality can be expected in the finished cheese. Most operators prefer to use pasteurized-milk cheese on this account. After the cheese is cured, the wrapper is stripped from the block and the cheese is cut into small units and wrapped again for retail sales. All of these operations are performed in some factories, but the final cutting and wrapping are commonly done in packaging plants where these operations can be performed mechanically. The operator of the packaging plant may also be the merchandiser and distributor of the product.

Mold inhibiting compounds have been used on packaged cheese, but sorbic acid at present is the only one approved for general use by the Food and Drug Administration. Bags or wrappers that can be sealed under vacuum have been used successfully to package blocks of Swiss and slices of cheese. They have also been used for packing cheese in an inert gas. Unless more effective mold inhibitors are approved, it seems probable that exclusion of oxygen from prepackaged cheese may become even more important.

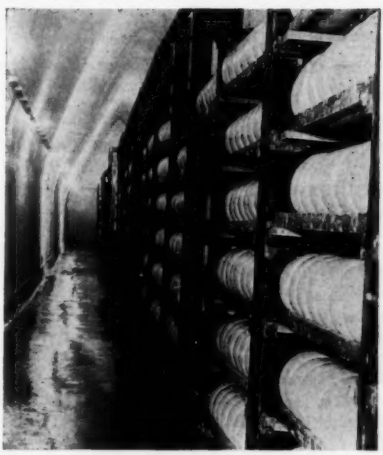
Jars and foil-wrapped packages of ground, blended cheese were sold commercially in the early 1900's; it was known as Club cheese. Units weighed from a few ounces up to 5 lb. Similar products are now sold in almost identical containers and also in the small sausage-like links. Shaker-type containers, popular for table use, are used for distributing grated, dried Italian cheese.

Fancy Cheese

Types of cheese other than Cheddar became known in industry as "fancy cheese" in the early 1900's. The term is used here to include cheese of foreign origin and products which were modified or developed in the United States.

There were strong advocates for new kinds of cheese 50 years ago. It was clear, however, that those who dared to make them would have to cure and merchandise them, and the risks involved were great. Methods of making Camembert had been demonstrated on a laboratory scale at Storrs, Conn., but industrial production was handicapped without reliable refrigeration and humidity control. Few plants were started and only a few still operate today.

Roquefort-type cheese made from cow's milk had a history similar to that of Camembert. A



Blue cheese curing cave.
(by Treasure Cave)

few commercial organizations were interested in the laboratory developments. The Iowa method, which used the homogenizer, shortened the making process and soon was adopted by manufacturers in Iowa, Illinois, Minnesota, Wisconsin, and Oregon. The manufacture of the mold-veined cheese in this country is unique because it has been developed largely by over 50 years of research in at least six laboratories.

The manufacture of Swiss cheese was already established on this continent 50 years ago. Improvements in methods have come chiefly from intensive research and introduction programs. The European influence through the literature and the work of Swiss-trained cheese makers must be acknowledged. The value and influence of the contributions of L. A. Rogers, E. G. Hastings, J. M. Sherman, K. J. Matheson, W. C. Frazier, and their associates have been outstanding. The introduction of scientific methods by C. M. Gere, C. F. Doane, R. E. Hardell, C. A. Buck, R. Farrar, and F. Feutz was essential. New starters, clarification, milk quality control, milk standardization, and curing room practices were first studied and then applied in every Swiss area. No other branch of the cheese industry has profited so much from the expenditure of public funds.

The patent disclosures of J. B. Stine of the Kraft Foods Co. and their applications since 1950 have caused radical changes in making and merchandising Swiss cheese. Producing square blocks of Swiss instead of traditional round wheels facilitated economical wrapping, curing, and storing. Many Swiss factories have revived the old art of pressing cheese in blocks. They wrap the salted blocks in moisture-proof, essentially air-tight films and cure them in boxes. In this way they avoid the laborious treatments of curing the traditional Swiss. The amount of Swiss cheese made yearly in the United States has increased fourfold since 1920 to a total of over 110,000,000 lb. at present. The increase from 81 to 110 million pounds per year since 1949 underestimates the increase in production by the Stine method.

"Iowa" Swiss is a product made in several states by water-washing a granular curd. It is a sweet cheese with the small, shiny eyes of Swiss and the flavor imparted by the use of propionic, acid-producing organisms.

The Italian cheese industry developed after World War I. Large investments required for curing the cheese and the restricted markets were obstacles at first. The expansion and recession of production experienced during and after the war periods indicate the hazards in this industry. It is being developed today with new customers and interesting new products.

The making of skimmilk Cheddar was important 40 years ago, but the passing of the free lunch counter took away its chief market. A New York dealer declared it was the only cheese he could keep on the sidewalk unprotected overnight.

Dutch and French types of soft ripened cheese have achieved distinction since the 30's. Methods of making have not been completely described and much of the special equipment has been patented. Some atypical Edam cheese was well known during World War II. It was usually made by Cheddar factories attempting to avoid set-aside orders or price controls. Its popularity ended with the war. Greek cheese has been made in small amounts by very few factories during the past 50 years.

Soft Unripened Cheese

The chief products in this class include cottage, bakers', cream, and Neufchatel. Cottage cheese was usually made from raw milk 50 years ago. In 1917 pasteurization, draining in a cloth, and rinsing with water were advocated. It was in the 20's that sweet-curd, rennet-type cottage cheese became popular on the west coast. Developments since then have been: greater use of pasteurization; use of nonfat dry milk, cultures, acid control, creaming and packaging equipment; and improved sanitation for quality control and increased shelf life.

Cream and Neufchatel cheese production in 1906 was by traditional European methods. Bakers' cheese is still made in that way, although some curd is made by centrifuging or using a filter press to remove whey. In the 1920's an improved cream cheese in 5-lb. loaves was developed. The essential steps of making it from homogenized cream distinguished it from the older methods. In 1927 a novel use of the homogenizer for making cream cheese without draining bags was developed at Geneva, N. Y. Others have explored the possibilities of this method with other combinations of ingredients. Centrifugal separation is the newest method of separating cream cheese curd from whey.

Processed Cheese

The marketing of processed cheese in 5-lb. loaves in 1921 marked the beginning of a new era in the cheese industry. The Phenix Cheese Co. and J. L. Kraft and Brothers Co. owned the basic patents; the two companies merged eventually to form the Kraft-Phenix Cheese Co. The new product was nationally advertised and distributed and probably increased the use of cheese. Opponents of cheese processing accused the industry of using inferior materials and preservatives. To these accusations Kraft replied that the cooking actually pasteurized the cheese and the package gave it complete protection. Processed cheese soon moved into Canada and Australia; it was marketed in tubes like shaving cream and in packages for individual use.

In 1930 the purchase of the Kraft-Phenix Cheese Co. by National Dairy Products Corp. was announced. As this decade ended, the basic patents expired and new manufacturing

Norman Kraft
"Imagineer"

J. L. Kraft
President

operations were started. Practically all authentic publications on processed cheese had been printed at that time in the *Journal of Dairy Science*.

Processed cheese during World War II was canned and used wherever troops were stationed. Cheese for civilian use began to appear in cellophane, wax-coated wrappers instead of tinfoil. One of the outstanding developments during the past few years was the invention of machines and methods for making processed cheese and packaging it in slices.

Over 60% of the ripened cheese produced in the United States is marketed in some form of processed cheese today.

Grading

Marketing cheese from the factory requires identification of quality at an early age to help establish its commercial value. Wisconsin established compulsory grades for Cheddar and Swiss in the 20's. U. S. grades for Cheddar were activated in 1923 and for Swiss somewhat later; these are voluntary grades. Continuous inspection and certification of grade of cheese under production is a service offered in recent years by the federal government. It has been used chiefly by processors of cheese.

Standards and Definitions

In 1906 cheese was branded only to identify its fat content. There were few moisture laws; these were not developed at the federal level until after 1916. In the meantime New York and Wisconsin had set moisture limits at 38 to 40%. Wisconsin eventually required informative labeling of high-moisture cheese.

Compliance with sanitary regulations in factory practice has always been attained partly by enforcement and partly by educational means. The sanitation requirements of the Food, Drug, and Cosmetic Act of 1939 helped the cheese industry modernize facilities and methods. Discussions by enforcement officials set a new pattern for responsible management at every level of production and handling.

Carl Marty Sr.
Swiss Cheese Maker

Standards and definitions of cheese under the empowering act of 1939 were developing in the 40's. Industrial and scientific knowledge, trade practices, and consumer needs were considered before these remarkable standards and definitions for natural and processed varieties were published on August 24, 1950. Their scope and specificity are notable. They have already exerted a strong beneficial influence on cheese production, processing, and merchandising but have not prohibited development of new products or improvement of old ones.

The words of Samuel Johnson may be a comfort to those who have played their part in the cheese industry; they may be both advice and inspiration to those who carry on the work:

> "The philosopher may be delighted with the extent of his views, the artificer with the readiness of his hands, but let the one remember that without mechanical performance, refined speculation is an empty dream, and the other that without theoretical reasoning, dexterity is little more than brute instinct."

Ice Cream Manufacture

P. S. Lucas

Dairy Department, Michigan State University, East Lansing

In retrospect, the changes in the ice cream industry during the past 50 years may seem to be primarily the advances made in merchandising and in sanitation, but for the consumer who lived in the early period the changes are largely those of price. Although consumer prices are higher today, the increase is relatively less than that in machinery, labor, and material costs confronting the manufacturer. The methods used in making ice cream of superior quality in 1906 were extremely cumbersome and expensive by today's standards. For example, the 10-day aging period involved then would be impractical today because of the additional space and equipment required. The freezing process at this early date was one involving the use of a motor-propelled 10-gal. can placed inside a tub packed with ice and salt—a great contrast to the high-capacity continuous freezers of today.

P. S. Lucas

The soda bar and fountain of 1906 brings nostalgic thoughts to many old-timers. Located ordinarily in the rear of a drugstore, it was a vast expanse of glass and marble with seating arranged to accommodate several persons. The serving glasses held between 10 and 12 oz., and the flavors were largely synthetic. An ice cream soda cost five cents, and the ambition of the average youngster was to consume as many as his resources permitted, regardless of later consequences. A multiplicity of tempting concoctions was absent, although sundaes were beginning to come into vogue.

The sale of ice cream at this early date was by no means confined to drugstores. There were establishments known as ice cream parlors, which served a variety of flavored ice creams. These stores usually sold candy also. There were ice cream soda bars at most of the amusement parks. Usually a considerable space was given over to table service in such places. The "hokey pokey" man and his wagon with its string of bells to announce his approach was a familiar sight along the dusty streets of each fair-sized city, and the ice cream social was the favorite method of raising money by practically all church and lodge groups. Many homes had their own facilities for making ice cream, using salt and ice tub hand freezers and a mix made largely of cream, sugar, and eggs. Ice cream in these early days was associated with special events.

Ice Cream Takes Hold, 1906-1916

During the first decade after 1906 many universities began offering courses in ice cream manufacture, the first such course having been given at Pennsylvania State College in 1892. Much of the early teaching was foreign to many of the practices in vogue today and was largely a trades school approach. The industry used colors made from such materials as spinach (green), carrots (yellow), cochineal (red), and indigo (blue). The use of the extra milk solids in the form of concentrate was considered as a sales promotional effort by condenseries to increase the market for their products. The amount of ice cream manufactured in 1909 was only 80,000,000 gal. but by 1916 it had increased to 280,320,000 gal.

The first brine freezer was made in 1900 by Edward Walker, of Warren, Pa. In the same year a movement was started for exchange of ideas among industry members by a meeting held in Illinois, which crystallized a few months later in the Three I's Association, including the states of Iowa, Illinois, and Indiana. This association later became the International Association of Ice Cream Manufacturers and has been the principal influence in the formulation of manufacturing policies since that time. One year previous, 1905, the *Ice Cream Trade Journal,* devoted entirely to ice cream problems, was established by Thomas D. Cutler, who is now living in retirement in New York. This journal must be credited with a major role in developing the ice cream industry of this country. Mr. Cutler's dynamic energy was directed to quite an extent to the technical phases of the industry, whereas the major portion of attention today seems to be given over to merchandising methods.

The first appearance of the ice cream cone was at the St. Louis World's Fair in 1904. These cones, baked as thin wafers and rolled while hot around a wooden form, were delicious and became a common article of sale at all carnivals and fairs of the period.

Far-seeing leaders in the industry felt the need of standardizing their product and even though the persons attending the early meetings of the N.A.I.C.M. were few, enough were assembled by their first secretary, Nathan Lowenstein, to form a solid core of progressive thought. Among these early leaders must be mentioned such stalwarts as John Knobbe, John Cunningham, Nelson Dessert, and W. F. Luick. In 1906 the Association recommended regulations for the industry to the Federal Food and Drug Division, and the U. S. Secretary of Agriculture established the first ice cream standards. Although the federal standard called for 14% milk fat, many of the states

maintained a standard as low as 8%. The high federal standard was fought through the years by manufacturers, but criticism was especially harsh in 1908. The problem was brought before the U. S. Supreme Court in 1919 by industry members with the result that much confusion ensued regarding correct fat standards for interstate shipments of ice cream. Eventually no United States standard was held to or enforced.

In 1906 the National Association called for regulation of plant sanitation and began a campaign for quality. That their actions were productive is shown by the tremendous increase in ice cream sales. Automotive delivery of ice cream began in 1911, and by 1918 most plants were using motor-driven trucks. Express rates were topics of interest at all times, and the Interstate Commerce Commission was in frequent controversy with the industry over inequality of such rates. Quite naturally, with the industry growing as fast as it did, and, in a period when the muck-raking reporters were enjoying a heyday, the newspapers were demanding ingredient labeling of packaged ice cream, and the critics of the industry were suggesting the sale of ice cream by weight. By 1916 newspaper articles had appeared purporting the use of river water in ice cream, glue for stabilizer, and gross insanitary conditions in the plant. The period immediately before World War I was one of tribulation but in reality a good one for the industry, since it served as a grim awakening for some of the few who were taking advantage of lack of adequate inspection and intelligent sanitary methods. In 1914, placing on the market of the Mojonnier fat and solids tester was especially sensational.

The Foundation Is Laid, 1916-1926

The decade beginning in 1916 featured inventions and methods that set a pattern for merchandising and technical adjustment. It was a period that, in a sense, might be termed a foundation upon which the present ice cream industry was built. It was marked (1920) by the start made in the practice of standardizing mixes, the experimentation which set limitations upon the ingredients that might be used in ice cream, the introduction of mechanically refrigerated ice cream cabinets, and more rigid standards for ice cream. The period covers World War I, when shortage of supplies threatened the very existence of the industry. Nothing was considered too good for the American soldier, and the American soldier wanted his favorite ice cream. Perhaps this did as much to stop the utter suppression of ice cream making at this time as any other single factor.

Talk among industry members as early as 1916 was directed toward the need for a mechanically refrigerated ice cream cabinet in order to do away with the messy ice and salt cabinet with all its attendant evils. It was not until 1923, however, that Glen Cowan, of the Arctic Ice Cream Co. of Detroit, perfected and placed on the market the Nizer ice cream cabinet. At the same time he offered to the industry a correspondence course on the operation of the cabinet and the principles involved in mechanical refrigeration. As would be expected, the criticism was made that the expensive mechanical cabinet was a move to place the ice cream business in the hands of large producers who had the capital necessary to purchase such equipment. Other companies quickly followed in the production of the iceless ice cream cabinets, and their use spread rapidly.

Dry ice was introduced to the trade the same year as the ice cream cabinet (1923) and has been used extensively ever since for refrigerating ice cream in shipment.

A few people may remember some of the management questions of this period, such as the fight to enforce and establish ethical advertising practices. Aiding the progressive development of the industry was the work, started in 1917, on a model accounting system for ice cream plants, the formulation of quality standards by the National Association, and the passage of uniform laws and regulations. These moves were important from a public relations standpoint. By 1920, overhead shafting and pulleys were on the way out; they were replaced with direct-drive individual motors.

Mojonnier Brothers Co. introduced the first automatic ice cream packaging machine, and the direct expansion batch freezer appeared in 1920. A successful industry always attracts the unscrupulous, and many cases were prosecuted for the introduction of foreign fats, especially peanut oil, to replace milk fat. Experiment stations began work at once on tests for the detection of foreign fats in cream. In 1921, the proponents of selling ice cream by weight brought their arguments into the courts of California and were defeated.

Although the Eskimo Pie was considered a novelty at the time, its appearance (1922) marked an important epic in merchandising ice cream. Next to appear was the frozen sucker (1923). Many other such items were introduced but none attained the popularity of the Eskimo Pie, which is still an important item in the industry. Incidentally, the general adoption of the mechanically refrigerated ice cream cabinet, in 1923, made the handling of novelties more convenient. The ice cream association became so concerned at this time about the inroads made into the industry by the selling at carnivals and fairs of low-fat products called custards that they successfully petitioned the Federal Trade Commission to stop the use of the name "ice cream" for such products.

During the period from 1918 to 1924 great technical advances were made in the manufacture of ice cream, many of them motivated by abuses perpetrated by some manufacturers. Nonfat dry milk solids had been found to be

of great value in building body. Some reputable manufacturers believed that if some solids were good, more would be better, and some ice creams were produced testing as high as 50% total solids. Needless to say, sandy ice cream resulted. No one knew the cause until finally the crystals were identified as those of lactose. This led to extensive studies to determine how much nonfat milk solids could be incorporated in the mix without causing the precipitation of lactose crystals in the stored ice cream.

In this period the emulsifying machine was introduced. Designed primarily for the small operator to replace the expensive homogenizer, it relied on centrifugal force to produce the required emulsification. This method helped texture but did not produce the results expected of homogenization. When this system went out of use, a less expensive type of homogenizer, which relied upon the breaking up of fat by passing it through a perforated steel disk, was placed on the market. There were many of these rotary type machines, and although they did excellent work initially the orifices eventually became enlarged by the passage of mix through them at high pressures, thus reducing the efficiency of the machines.

In this period too, carbonation of ice cream was tried. The experiment was interesting, but the "Purer because Carbonated" idea did not long continue. At this time was worked out the fundamentals of supplementary corn sugars to replace sucrose. Determination of the sweetening value of corn sugars was desirable so that they could be used to relieve the shortage of sugar supplies and to build body into the ice cream by reducing its water content. Their usage was at first protested, especially by the sugar interests and by law-enforcing agencies, but today they are seldom questioned.

Prior to 1920, gelatin was commonly used in sherbets and ices, where it caused excessive overrun. The use of gum stabilizers, introduced about 1921, completely removed this difficulty. Further advances in sherbet and ice manufacture resulted from the use of corn sugar, which removed the bugaboo of bleeding and petrified ice.

Stringent regulations and laws were passed, which required the making of ice cream in places other than basements. This had the effect of removing ice cream manufacturers from questionable surroundings and resulted in the reduction of the number of small, ill-equipped factories.

The universal adoption of homogenizers and batch freezers of both the brine and direct expansion types removed the old problems of aging cream and the difficulty of obtaining controlled overrun. Changes were made from brine hardening to direct expansion and flooded ammonia systems and finally to forced air and freezing tunnels. Large-scale operations were in the making.

The Years of Up-Building, 1926-1936

By 1926, ice cream consumption per capita had increased to 2.77 gal. The previous 20 years, therefore, marked great advances in the public's appetite for ice cream. During that period the hopper system for mass production of ice cream and the use of freezers of large capacity were developed. The first mechanically refrigerated truck was shown at the Dairy Show in October, 1926. The Vogt freezer of 1927 embodied the principle of pumping air into the mix as it was frozen in a drum much smaller but resembling the barrel of the batch brine freezer. This and the Creamery Package type of continuous freezer readily lent themselves to adequate control of overrun and to such devices as fruit feeders and such accessories as those used for making Neapolitan ice cream. Many other technical advances were made during this period. Glass-lined and stainless steel pasteurizing vats were introduced. These replaced the old style coil vats.

The inroads on sales of gelatin were particularly noticeable in the thirties. The need was for less expensive stabilizers having the stabilizing qualities of gelatin and, if possible, producing required viscosity or plasticity without aging. Foremost among these were the sodium alginates; others were mixtures of gum, gelatin, alginates, methyl-cellulose, locust bean gum, and sea moss derivatives. Many of these stabilizers still hold their popularity.

In the thirties, short-time, high-temperature pasteurization was the main topic of conversation among milk processors. Much exploratory work was done during the period on the application of this process to ice cream mix. Two factors combined to encourage this system: the advantages of the vacuum method for pasteurizing milk and the importation from New Zealand of the Vacreator. Details of methods and the determination of the proper temperatures for using HTST pasteurization equipment for ice cream mix have been published. The advantages of this method in speeding up operations and in reducing expensive floor space in the plant are well known. The adoption of such an improved method has been slow since so many factors have had to be considered, such as the effect upon pasteurization efficiency, protein stabilization, body and flavor, cleaning procedures, and costs.

Much was done in this period to bring about a change in the method of handling ice cream for sale. Greater emphasis was placed upon sale of ice cream for home use. Packaged ice cream was believed by the consumer to contain more overrun than was found in bulk ice cream. As any ice cream man knows, the reverse was true, but the dipping of ice cream forced out much of the air and resulted in a heavier pint or quart, which was soon evident to the cost-conscious consumer. During this period, bulk sales amounted to approximately 67% and packaged goods, 33%. However, the change

taking place has been so rapid that at the present time more packaged goods than bulk are sold.

One of the ice creams that proved popular in this period was peppermint stick. A laborious method was first used to make this product. Stick candy was broken and heated to make a syrup, which was then added to the ice cream. The popularity of the peppermint flavor led to the use of other candies in ice cream. One of these, chocolate chip, was made originally with broken pieces of chocolate chip candy. Another method was to punch a hole in a can, fill it with chocolate coating syrup and permit the sirup to flow in a small stream into the partially frozen ice cream. The chocolate solidified at once and assumed in the ice cream the form of small drops. Little flavor was added by this method. At the present time the product is made almost entirely from a candy chocolate.

Candy flavors have been augmented with many others, the latest addition being apple. Fruits have been added in the form of purees and ripples. The standard extracts have undergone changes; in some states more fortified flavors are used at the present time than were used earlier, but the quality is now improved and in general it may be said that the public is being given better flavored products today. For instance, citrus flavors have been greatly improved by the development of methods of removing troublesome terpenes, thus avoiding the bitter flavor caused by the oxidation of the terpenes.

In the period under discussion most of the chocolate ice cream was made from cocoa, but there was a trend toward the use of mixtures of chocolate liquor and cocoa. Because of the richer texture the mixture imparts and the increase in mellowness of flavor, this has come to be common practice.

In the sanitary field the changes and the progress made have been gradual and constantly for good. It was realized that the fact that ice cream is frozen does not necessarily mean that it is safe for human consumption. There has been constant improvement in the raw products entering into ice cream, and since 1920 practically no infections have been traced to ice cream—a remarkable record for a food product so commonly used.

The slack period resulting from cuts in production during the depression years did not prove entirely unprofitable to the industry because it brought into focus the crying need for laboratory control of products. Perhaps this was hastened by the passage, beginning in 1925, of state laws setting bacterial standards for ice cream. Naturally, when ice cream samples were found to contain high numbers of bacteria, the sources were sought in equipment, such as boxings in homogenizer heads that could not be disassembled for proper cleaning and beaters, scrapers, and unloaders in the freezer, which did not lend themselves to easy cleaning. This led to redesign of much of the equipment used.

Competition was so keen in the period of the depression that some questionable practices were resorted to. The double dip cone was the sensation of the day, and cut-rate prices were the rule. To meet such competition it was necessary that the manufacturer sharpen his pencil, and, although standardization of mixes had begun in 1920, it became the common practice during the depression period when it was necessary to cut costs in the interests of economy. Overrun control became a common practice.

In this period much work was done on technical problems in ice cream making. However, since this time, research in the ice cream field has become limited and the trend has been decidedly in the direction of the basic chemistry and bacteriology of milk and milk products. This does not mean that there is less interest today in ice cream but rather that the practical problems of the early period were greater and more urgent than those of today.

The War Years—1936-1946

The period of 1936 to 1946 covers a time of readjustment in the ice cream industry. During the entire period, and especially the war years, fruits and the raw materials for any dessert food became scarce and high-priced. With the scarcity of desserts caused by the needs of the war camps, ice cream became increasingly depended upon as a source of material for desserts in the home. The limiting factor was again, as it was in World War I, sugar, but the industry did not suffer seriously. Vanilla was scarce, but the market at no time became entirely depleted of this flavoring. Tropical materials, such as coffee, chocolate, and the vanilla bean, skyrocketed in price because of scarcity.

At the beginning of the war, ice cream had been classed as a frozen dessert and as such was denied a full quota of sugar. Its classification in 1943 as a food proved helpful to the industry in obtaining suitable quotas, although serious limits were placed on the amount of total milk solids that could be used. In 1945, butterfat controls were canceled and the industry began to enjoy post-war recovery.

Because of the low purchasing power of the public during the forepart of the 1936-1945 period, a major problem of the industry was the production of inexpensive packages that could be sold at a low price. Many factories made a low-priced ice cream by increasing overrun. As a consequence, over 15 states enacted laws regulating overrun. Laws were also passed regulating wages; Social Security was enacted; hours of employment were specified; the W.P.A. was established; and similar moves were made to alleviate the condition of the worker. Manufacturers faced the problem of some dealers bootlegging their products into ice cream cabinets other than their own, which

enabled them to reduce prices. Some attempts were made to establish trade barriers. These were not imaginary barriers; they were real and some of them still exist. By 1940, cooler heads had ameliorated the situation by compromising many of the disputes and senseless regulations.

During this period of slack sales, manufacturers of refrigerating equipment were glamorizing their plain cabinets into attractive units. Work was begun on the deep-freeze cabinets for homes, and new refrigerating chemicals were perfected. The open-top cabinet was developed and, when its great selling possibilities were demonstrated, the way was paved for the sale of ice cream from food stores.

The Industry Grows Up: 1946-1956

A vigorous industry usually recovers quickly from batterings such as the ice cream business suffered during the war years. The release from the anxiety and privations of World War II called for celebration by the public. Consequently, 1946 was a big year for the ice cream industry. Imported products could be obtained, at least in limited quantities. However, some scarcities still existed, owing to the neglect during the war of cocoa bean production and the disorganization and retrenchment policies of industries catering to the ice cream trade. At the same time there was a plethora of labor disputes, most of them resulting in increased labor costs. The spiral of costs was continuously upward during this decade.

By 1950 the production of ice cream had reached 537,000,000 gal. and the industry employed 80,000 men. The gallonage of ice cream for 1954 was 542,373,000; of sherbet, 34,048,000; and of ice milk, 78,742,000.

In 1945 the War Production Board estimated the number of soda fountains in the United States at 120,000. Ice cream was sold in 40,000 drugstores; in 40,000 confectioneries; in 15,000 restaurants; in 2,000 variety stores; in 400 department stores; in 5,000 specialty shops, and at 17,500 fountainettes. During the war period, which is sometimes referred to as the golden age of the package, the shift from bulk to packaged ice cream began in earnest. Automatic ice cream packaging came into the picture in 1947, and the following year the half-gallon package started its long run of popularity. In 1951, as compared with 1941, bulk dropped from 63% of sales to 46%. Packaged sales climbed from 20% to 29% of total output, cup sales increased from 5.4% to 6.4%, and frozen specialties increased from 11.35% to 17.2%. In 1952, the half-gallon package had convinced manufacturers that it was here to stay; in 1953 sherbets were packaged in these containers; in 1950, 3.86% of all sales was in half-gallon containers, and in 1955, 25%, or a total of 186,000,000 gal., was sold this way.

With America riding the highways, the way was open for ice cream stands selling soft ice cream. The number of Dairy Queen stores, started in 1940, had grown to 2,500 by 1955. Ice cream vending machines were to be found in theaters, railroad trains, and army bases. A richer than usual ice cream made its appearance in 1947; the ice cream cake roll appeared in 1949. In the earlier fifties vegetable-fat products entered the picture, and unofficial figures placed the quantity produced in 1955 at 80,000,000 gal.

The Look Ahead

However the future may appear to different individuals, there are conditions in industry in general which should thrill even the most optimistic. In the first place there is a minmum of unemployment and industry sees no lack of employment in the immediate future. This means that there is an abundance of purchasing power, and purchasing power means sales. In addition, population is increasing at a rapid rate, and changes from rural to urban areas mean greater purchases by consumers. Even for the country dweller, ice cream is becoming readily available through the operation of rural ice cream routes. People living in cities are purchasing combination refrigerators and home freezers, and sales have increased rapidly as a result of this home storage of ice cream. The great increase in the employment of women has caused increased demand for ready prepared desserts. Also, more people are eating their meals outside the home, and ice cream is a favorite dessert on such occasions.

The dealers have contributed greatly to increased sales by the use of better merchandising methods, and the manufacturer has been aided immensely by store selling. Not only is the availability of ice cream enhanced by store selling, but the items are constantly before the potential purchaser as a reminder of their availability. Improvement in package attractiveness also has increased store sales. In addition, the increase in numbers of flavors has added zest to the purchase. Improved quality has further increased consumer acceptance and in turn has resulted in increased business for the manufacturer.

The Development of the Evaporated Milk Industry in the United States

E. H. Parfitt

Evaporated Milk Association, Chicago, Illinois

Although the evaporated milk industry is relatively young, it had its beginning in the 19th century. For this reason it is desirable, before going into a discussion of the last 50 years of growth and development, to point out certain of the milestones which occurred during the 1800's. The search for a method of keeping milk in a condition as nearly as possible like that in which it came from the cow is a fascinating story.

E. H. Parfitt

History records that it was Nicholas Appert, an obscure confectioner in the outskirts of Paris, who was the first to evaporate and preserve milk by heat in a sealed container. His experiments on food preparation were begun in 1795 when France, under Napoleon, was fighting most of the other nations of Europe. Need for transportable food for the far-flung French armies had prompted the French government to offer a prize of 12,000 francs to anyone who could find a satisfactory method of preserving food.

Toiling in a tiny kitchen back of his shop, patiently cooking first one food and then another, Appert discovered that he could keep foods for long periods of time by cooking them, sealing them air-tight, and then cooking them again. After 15 years of experimenting, he announced his results, and on January 30, 1810, he was awarded the prize. It is remarkable that Appert, knowing nothing of bacteria, had come to the correct conclusion that food cooked and sealed would remain in good condition. It was another Frenchman, Louis Pasteur, who many years later, by demonstrating the nature and behavior of microscopic organisms, solved the riddle.

Appert's milk process consisted of reducing a given quantity of milk to one-third its original bulk by boiling in an open kettle. This milk he then put into bottles, which he corked tightly and heated again in a hot water bath. The strong cooked flavor that resulted in Appert's process can easily be imagined—and he was not aware, of course, of the destructive effect on certain vitamins of the combination of free access to air and heat. Though Appert's evaporated milk in no way resembles that of today, he demonstrated that concentrating milk was practical.

While Appert was at work, others in both France and England were experimenting in milk preservation by evaporation and the addition of sugar. The early French and English patents obtained for such purposes were the forerunners of the sweetened condensed milk we know today. In 1813, a patent was obtained in England for a "vacuum pan," now a most important piece of equipment in the evaporated milk process. It is in such pans that the milk boils vigorously at the low temperature of around 130° F., and half of the water is removed without important effect on the vitamin content. In England in 1835, a vacuum pan was used for the first time in connection with milk evaporation.

In 1853 Gail Borden applied for a U. S. patent on his idea of preserving milk in a semi-fluid state after evaporation in vacuo. This followed some 10 years of experimentation. In August, 1856, he received patents from the United States and England. Although the claim of the patent granted Gail Borden was that of "producing concentrated sweet milk by evaporation in vacuo without the admixture of sugar or other foreign matter," Mr. Borden's commercial development was in the manufacture of sweetened condensed milk. Equipment design has greatly changed, but the principle of the vacuum evaporator developed by Gail Borden is still a foundation of the industry. Gail Borden's original vacuum pan can be seen today at the Smithsonian Institution, Washington.

On January 1, 1857, an English patent was granted to Joseph House, for preserving unsweetened evaporated milk. He produced some milk on a commercial scale, but the product was injured to such an extent by the heating that it did not find favor.

It took another war, this time in our country, to demonstrate the usefulness of a storable, transportable milk. At the close of our Civil War, the story of the success of sweetened condensed milk was carried to Switzerland by Americans, and the first European plant was shortly established there. The man placed in charge of the processing and packaging in this plant in Cham, Switzerland, was John B. Meyenberg. It was his conclusion that milk from which only water had been removed and to which nothing had been added would be the most convenient form for the largest number of purposes—milk evaporated and sterilized.

Since he could not interest his organization in his idea, he crossed the Atlantic and eventually landed in St. Louis. There a Swiss countryman and dairy farmer, school teacher Louis

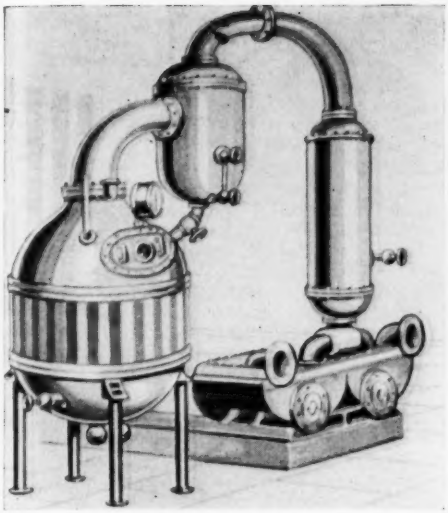


FIG. 1. One of the first vacuum pans used. (Helvetia Evaporated Milk, Highland, Ill., 1885)

Latzer, had faith in his idea. Together with a group of Swiss dairy farmers in Highland, which was about 30 miles across the Mississippi in Illinois, they formed a company to operate the first unsweetened evaporated milk plant in the United States and in the world.

In 1884 Mr. Meyenberg received a United States patent which covered the process of sterilizing by steam under pressure while the cans are agitated. This is the basis of the sterilization process still used throughout most of the industry. In the following year evaporated milk was first manufactured commercially in the United States.

The dependability of evaporated milk as a safe, sterile, transportable concentrated whole milk supply for maintaining the health of the men in the armed forces was ably demonstrated during the Spanish-American War.

The year 1901 brought machine-made evaporated milk cans to replace those that were fabricated by laborious hand-work. The early machines produced about 60 cans per minute in contrast to present-day machinery, which turns out cans at about six times that rate.

Introduction of Homogenization

Homogenization was introduced in the manufacture of evaporated milk in 1909 to stabilize the emulsion and retard fat separation. This process resulted in a substantial increase in the period of time that the product could be held in storage without physical change. This was the first application of homogenization in the dairy industry and was universally adopted by all manufacturers. Homogenization did much to increase consumer acceptance of evaporated milk during this early period.

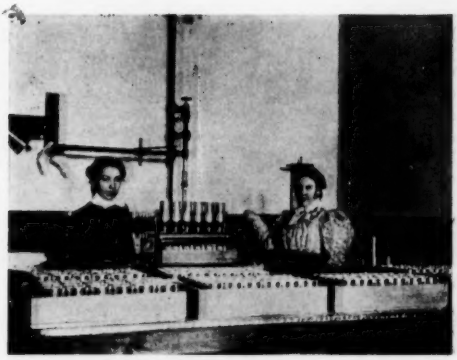


FIG. 2. Filling machine in an early evaporated milk plant.

Millions of cases of evaporated milk were used to supply the need for whole milk for the armed forces of the United States and its allies during World War I. At this time evaporated milk was the only commercially important form of storable whole milk suitable for every milk use. Evaporated milk was hailed as a boon to the fighting man. Between 1914 and 1918 annual production more than doubled. Service men who had been introduced to evaporated milk during the war went right on using this "armor-plated" milk when they returned to civilian life.

1918 to 1920 saw large-scale use of evaporated milk to feed the starving people of war-devastated countries. Millions of cases were shipped from the United States to feed the hungry of Europe.

Continuous Sterilization

In 1922 the continuous system for sterilizing evaporated milk was introduced. By 1956 this method had almost completely taken the place of batch sterilization.

In 1923 manufacturers organized the Evaporated Milk Association, the purpose of which was to institute and conduct fundamental research in the public interest and to develop an educational program to apply the fundamental information obtained by research.

Also in that year the U. S. Department of Agriculture promulgated an advisory standard for "Condensed Milk, Evaporated Milk, Concentrated Milk." This standard called for 7.8% milk fat and 25.5% total milk solids, which had been the standard used by the principal evaporated milk manufacturers for some 10 years previously. In 1926 the definition was clarified by removal from the standard of any reference to concentrated and sweetened condensed milk.

By 1924 the increased consumer interest in evaporated milk prompted the Evaporated Milk Association to institute studies on methods of using evaporated milk in the preparation of superior foods, and recipes were developed for

popular use. This was followed by an intensive program of consumer education, supported by women's magazines and by newspapers. Home economics teachers, home economists with utility organizations, food editors, home demonstration agents, and others also helped disseminate information about better ways of using evaporated milk.

Clinical Studies of Milk for Infant Feeding

The year 1928 was the beginning of universal recognition of evaporated milk as the most advantageous form of milk for infant feeding, based on such properties as uniformity, sterility, and digestibility. It was discovered that the heat treatment during processing changed the physical character of the proteins so that they formed smaller and softer curds during digestion, which was of particular advantage to the small baby. The small fat globules resulting from homogenization present a larger surface and are more accessible to the fat-splitting enzymes, thus promoting faster digestion.

1928 also saw the beginning of lecture-demonstration work in college home economics classes. Similar work was begun with home demonstration agents, home economists, utility organizations, and consumer groups.

Establishment of the Experimental Kitchen

A fully equipped experimental kitchen was established in 1930 as a part of the Evaporated Milk Association. This was the first maintained by the industry. A home economics staff developed recipes for consumer use, for inclusion in a series of booklets, and for regular editorial services for food writers of magazines and newspapers. These services were expanded to provide food photographs with accompanying recipes in order to meet the demands of print media.

Beginning of Nutrition Service

By 1931 it had been established that evaporated milk was an excellent and economical whole milk supply for the entire family. To expand further the outlets for the product, educational work was begun with health and welfare agencies, medical schools, child care institutions, home economics departments in schools, colleges and business organizations, and agricultural extension groups.

By the early 1930's educators were beginning to recognize the importance of visual aids in the teaching field. An educational motion picture was developed in 1932 tracing the history of evaporated milk and showing its uses in modern-day living. This film was enthusiastically received by schools and consumer groups.

The Vitamin D Program

In 1933 the American Medical Association Council on Foods and Nutrition organized a vitamin D milk program to encourage the production and use of vitamin D fortified milk. Also in 1933, the *Journal of the American Medical Association* commented editorially, "Whatever the explanation may be, the fact remains that the incidence of rickets is still too great and will continue to be until some cheap, generally available, agreeable source of vitamin D is provided. Vitamin D milk seems to offer promising possibilities of meeting these requirements."

The following year brought the introduction of methods of increasing the vitamin D content of evaporated milk to 135 USP units per pint, either by irradiation or by addition of vitamin D concentrate. This pioneering step proved to be an important nutritional advance by providing a significant source of vitamin D, which promotes utilization of milk minerals for growth and maintenance of good bones and teeth. The use of vitamin D in evaporated milk and later in other fields of the dairy industry has provided an effective means for the elimination of rickets as an infant health problem.

Establishment of Standards

In 1939 an industry-wide voluntary sanitary standards program for the production of evaporated milk was inaugurated. It covers all phases of plant, milk, and farm sanitation, and it is accepted and followed by all plants and receiving stations. The standards and quality control methods of the industry have been widely approved at federal, state, and local levels.

In 1940 the evaporated milk definition and standard of identity was promulgated by the U. S. Food and Drug Administration. This standard required 7.9% milk fat, 25.9% total milk solids, and provided for the optional addition of 7.5 USP units of vitamin D per avoirdupois ounce.

Expansion During World War II

During this period (1940-45) millions of cases of evaporated milk were used to supply safe whole milk for the armed forces and civilians throughout the world. During one year more than 38 million cases of evaporated milk were so used. During 1945 alone almost 87 million cases of evaporated milk were produced, as compared to the prewar figure of about 48 million cases.

This increase in production of evaporated milk was brought about largely through increasing the capacity of existing plants and through the use of receiving stations for expanding the buying territory of a plant. Since World War II this trend has continued.

Adoption of Vitamin D Fortification by Industry

In 1944 vitamin D fortification of evaporated milk by the addition of pure vitamin D concentrate was inaugurated on an industry-wide

basis. Vitamin D addition was increased to 400 USP units per pint, the level considered to be optimum for meeting the needs of infants, children, and adults. This increase was subsequently supported by the American Medical Association Council on Foods and Nutrition and by the National Research Council Food and Nutrition Board.

Shortly thereafter it could be said that all evaporated milk marketed in the United States contained 400 USP units of vitamin D per pint. The level of vitamin D was controlled by a voluntarily accepted and financed check program.

The importance of vitamin D evaporated milk is illustrated by the low incidence of rickets today. In 1955 Dr. James R. Wilson, member of the Nutrition Committee of the American Academy of Pediatrics and former Secretary of the Council on Foods and Nutrition of the American Medical Association, stated: "It is difficult at the present time to find enough active cases of rickets in infants for purposes of teaching medical students." This is a tribute to the dairy industry.

The Postwar Period

As the supply of stainless steel became available, the large-scale replacement of coil type, single effect vacuum pans gained momentum. Tubular, double and triple effect vacuum pans

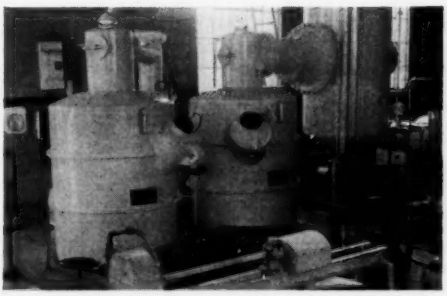


FIG. 3. A modern type of milk condensing vacuum pan.

of stainless steel construction were widely installed. Development of new types of equipment has enabled evaporated milk plants to concentrate fluid milk at a rate of nearly 50,000 lb. per hour. Filling and continuous sterilizing equipment was improved to the point that it could be operated at more than 200 cans per minute.

As subjects of interest to women were given considerably more space and attention in the metropolitan dailies in the postwar period, requests from editors for exclusive food features became more frequent. Editorial services were begun on an "exclusive on your coverage" basis for newspaper food editors and syndicate food writers. Demand for food photo-recipe features necessitated increased production of this type of material. An editorial service for women radio broadcasters was begun and was subsequently expanded to include women television broadcasters.

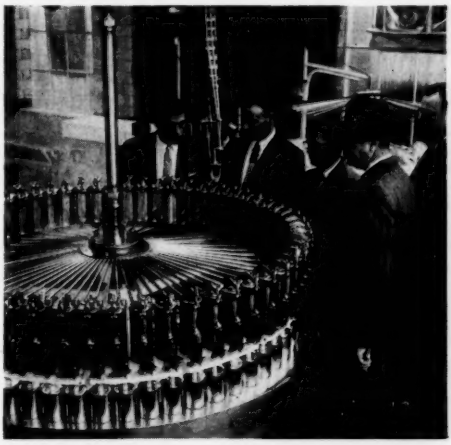


FIG. 4. Filling and sealing evaporated milk cans as done in a 1956 evaporated milk plant.

The trend toward wider use of visual and audio-visual aids as a teaching medium served as the impetus for an expanded program along these lines. In 1947 an educational sound motion picture was produced for school and consumer use. In the following years filmstrips were developed to teach mothers how to prepare infant formula and to teach use of evaporated milk in meal and food preparation at the high school and college level. Later a special editorial sound motion picture was produced for television and for use by schools and consumer groups. A filmstrip was developed with the cooperation of the Program Development Division of the Girl Scouts of the U.S.A. to be used in leader training and to teach Girl Scouts the principles of meal planning and preparation.

The Administrative Technologists Committee of the evaporated milk industry was created in 1949 to promote further research on evaporated milk at colleges and by the U. S. Department of Agriculture. Much fundamental comprehensive research work is now being done on heated milks.

The year 1954 brought the commercial introduction of evaporated milk sterilized prior to canning.

The Industry Today

From the beginning of commercial production of evaporated milk in 1885, the industry has grown to the point where there are hun-

dreds of brands of the product on the market at the present time. Evaporated milk is the largest single canned food sold in the United States—consumers open an average of more than 5,000 cans every minute.

The public has learned that evaporated milk is a safe, uniform, concentrated whole milk, but the search for ways of furnishing an even better product at reasonable prices continues. The industry's aim of supplying the consumer with this most convenient, versatile product moves forward as the results of research find practical application in the processing, distribution and sale of evaporated milk.

Dry Milk Manufacture

S. T. COULTER

Department of Dairy Husbandry, University of Minnesota, St. Paul

The concept of preserving milk by drying is very old, indeed. Marco Polo's account of the use of a sun-dried skimmilk product by the Mongols is familiar to all students of the early history of dairying. Presumably, the art and use of milk in this way did not persist among these people, possibly because of the decline in need with change in warlike habits. According to Beardslee *(1)*, the dry milk tablets produced by Nicholas Appert in 1810 were the first form of dry milk among Europeans. The tablets were made from milk concentrated slowly to a dough-like consistency in a current of heated air. Beardslee lists ten patents, five British and five United States, which were granted between 1835 and 1886 for various methods or processes for drying milk. All but one called for the addition of other materials, seven of sugar, one of sulfuric acid or some similar material, and one required the addition of an absorbent material and suggested the use of a carbonate of alkali, salt, borax, or some other preservative. The one not calling for additives was that of Percy, United States Patent No. 125,496 (1872), which envisioned, in general terms, the process of spray drying.

S. T. Coulter

There was additional experimentation and development during the remainder of the 19th century, but it wasn't until after 1900 that dry milk became a commercial reality.

The First Milk Drying Plant

The Rosemary Creamery Company at Adams, N. Y., operating in 1903, is credited with being the first commercially-operated dry milk plant in this country. They used an atmospheric roll drier, developed by the Merrell-Soule Company and originally used for drying a cereal-base product. Henry Dunham, of the Casein Company of America, experimented with a dough process for drying milk at Burlington, Vt., in 1900 and is stated to have later maintained an operation at Cherry Valley, N. Y., for three or four years. A plant utilizing a vacuum drum dryer was built by the Ekenberg Company, at Cortland Junction, N. Y., and was operating in May, 1905. The first successful spray process milk drying plant in this country was started by the Merrell-Soule Company at Arcade, N. Y., in May, 1906. This dryer was based on U. S. Patent No. 660,711, issued in 1901 to Robert Stauf of Posen, Germany, the rights to which were purchased by the Merrell-Soule Company. This dryer was operated originally on fluid milk, but later on precondensed milk, under U. S. Patent No. 860,929, granted in 1907 to Merrell, Merrell, and Gere. Beardslee *(1)* relates that, after a period of litigation, the Merrell-Soule Company made its process available to others, beginning in 1916. The patents held by the company, however, did not keep others from entering the field. The Central Creamery Company started spray drying milk in 1911 in a plant at Ferndale, Calif., using a dryer built under a design covered by U. S. Patent No. 1,078,848, issued in 1914 to C. E. Gray and Aage Jensen. A series of patents followed, culminating in what was to become known as the Gray-Jensen dryer, employing a cyclonic countercurrent drying chamber and a "wet collector" for prevention of entrainment loss and precondensing. The original Roger's dryer, which was a large box with spray nozzles located near the top on all four sides, was described in 1917 in U. S. Patent No. 1,226,001. The first dryer using a centrifugal atomizer was patented in Germany by Krause in 1912. The original experiments, both at the Merrell-Soule Company and by Gray and Jensen, were with air (two fluid) atomizers. In practice, however, high pressure nozzles were used. Two fluid atomizers have not been accepted by this industry.

Although dry milk was not produced commercially in this country until 1903, by 1906 all of the present commercially used processes were in operation. The dough process, which was the subject of much early experimentation, never came into extensive use. Likewise, a "flake" process developed by Campbell *(1)*, based on the same general principle, did not gain acceptance. Atmospheric roller dryers developed rapidly in importance. The first machine of this type to be widely used was that of Just, built under U. S. Patent No. 712,545 (1902). Similar equipment was later supplied by several companies, including Buffalo Foundry and Machine Company, Overton Machine Company (American Dry Milk Machine), and Mojonnier Bros. Company.

Vacuum drum drying was the object of extensive experimentation. The Ekenberg dryer has been mentioned previously. The Passburg, U. S. Patent No. 726,742 (1903), was developed at about the same time. The Buffalo Foundry and Machine Company constructed its first large-size vacuum drum dryer in 1909. Several other patents were granted for equipment of the same general type. Vacuum drum dryers, however, are no longer used, because of exces-

sive initial and operating costs in comparison with spray drying. Spray dryers in wide variety have been developed and are in use. This method of drying is now dominant.

Growth of the Industry

The growth of the dry milk industry has been spectacular and almost continuous. Production during the early years has been estimated by Beardslee *(1)* as follows:

Year	Nonfat dry milk solids	Dry whole milk
	(lb.)	*(lb.)*
1906	2,625,000	35,000
1907	3,750,000	55,000
1908	4,000,000	250,000
1909	4,500,000	300,000
1910	5,000,000	275,000
1911	6,000,000	350,000
1912	8,000,000	600,000
1913	10,500,000	1,000,000
1914	12,000,000	1,500,000
1915	14,000,000	1,750,000
1916	16,463,000[a]	2,123,000[a]

[a] Actual production reported by the U. S. Department of Agriculture.

Production since 1916, when USDA reports became available, is shown in Figure 1. Dry skimmilk from the outset has been the major product. The predominant use of dry skimmilk has been in human nutrition; nevertheless, up to 1940, a third or more was manufactured for

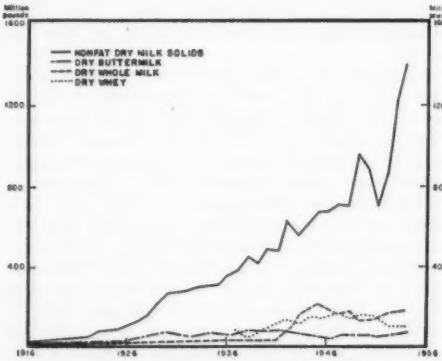


FIG. 1. Production trends of dry milk in the United States 1916-1946. Compiled from data issued by the USDA.

animal feed purposes. During World War II, the demand for milk for human nutrition forced conversion of equipment, and so of production, to meet the requirements. In recent years, animal feed production has represented only a small part of the total.

There was a very large expansion in total production during the war. Cook and Day *(3)* state, "Potential capacity during 1945, as an indication of capacity at the end of the wartime expansion period, is estimated at 834 drying units located in 499 plants capable of producing 308,560 lb. per hour. This was a 61% increase over the total 1940 potential capacity; a 74% increase in spray, and a 52% increase in roller."

The construction of new plants, or the installation of drying equipment in plants which had no drying equipment, either for human food or animal food, in 1940, accounts for approximately 51% of the increase. Thus, the largest part of the increase was made in areas which presented, in general, the most favorable possibilities for diversion from farm cream to whole milk deliveries. Of this increase, 42% occurred in Minnesota, and 20.4% in Wisconsin. The demand for human food during the war, therefore, not only forced diversion of production from animal feed to human food but brought vast quantities of skimmilk formerly fed to livestock on Midwest farms into plants for processing into human food.

Many persons consider one of the milestones of the industry to have been the enactment, in 1944, of Public Law 244, which in effect defined dry skimmilk intended for human consumption as "nonfat dry milk solids" or "defatted milk solids."

Expansion of the production of nonfat dry milk solids scarcely slackened with the close of the war and, during the past few years under a favorable government price support program, has surged. Utilization through normal commercial channels unfortunately has not kept pace with production.

Dry whole milk manufacture has never been more than a fraction of that of nonfat dry milk solids. Nevertheless, the volume is substantial and growth has been fairly uniform and continuous, except for the war and postwar periods. Obviously, dry whole milk was, to some extent, a "war baby." The war gains, however, have not been lost completely, and production now seems to be reasonably stabilized. Dry buttermilk production reached a peak in 1941. Declines since then may be attributed to the drop in butter production. Production of dry whey continues to increase; greater utilization as human food is a significant trend.

Dry milk in 1906 was a new product. Methods of manufacture were available, but production was limited to a very few companies. Uses for the product had to be found. Glabau *(4)* wrote, "The manufacturers of dry milk found it very difficult to introduce their product into the bakery. When it was first put on the market, most bakers could not conceive that milk could be dried to a powder, and when milk powder was mentioned, they looked first at the product, then at the man attempting to make the sale, with suspicion. Believing that it was some foreign substance to be substituted in

place of milk, they would not accept it, and thus it required very hard work and education to get them to use it in even small quantity. As the baker began to get better dried milk, he became more interested and gradually introduced larger quantities." Blackman *(2)* states that dried milk had its beginning primarily as infant food. Dried milk apparently gained early acceptance among at least some members of the medical profession. The bacteriological safety of dry milk and the constancy of its composition in comparison with the milk from individual herds were the two factors reported to appeal most strongly to doctors.

Standards Established by Industry

Actually, the dry milk of early manufacture must have varied widely in quality. First of all, manufacturers did not know enough about their product to know what to expect with respect to either initial quality or storage stability. Any standards were those of the individual manufacturer. Product standards as we know them today, did not come until 1930, when the Standards Committee of the American Dry Milk Institute suggested grades for dry skimmilk *(10)*. The various dry milk products today are all highly standardized. All may be bought on grade specifications with assurance of getting what is desired. This is one of the signal accomplishments of the American Dry Milk Institute, which, working with various governmental agencies, has secured the adoption of reasonable and beneficial standards.

The Problem of Oxidized Flavor

The early literature of the dry milk industry is largely contained in patents. Undoubtedly, the early manufacturers learned much about the characteristics of their products and the factors influencing their quality. Manufacturers soon recognized that a low moisture content was desirable. For example, Hunziker *(7)*, in the second of the many editions of his *Condensed Milk and Milk Powder*, states, "In order to insure keeping quality, milk powders must be as free from moisture as possible. Milk powders are not sterile, nor are they supposed to contain preservatives, such as sucrose and chemicals. Their only safeguard against bacterial fermentation and spoiling is their comparative freedom from water." Obviously, the reasons for a low moisture content were imperfectly understood. Dry whole milk was said to have a relatively poor, although somewhat variable, keeping quality. Spray-process dry whole milk was believed to be somewhat more susceptible to the development of rancid and tallowy flavors than the roller-dried product. Holm *et al. (6)* seem to have been the first to point out that there is a relationship between the heat treatment of the fluid milk and the susceptibility of the dried product to the development of a tallowy flavor. Research papers concerning dry milk first appeared in the *Journal of Dairy Science* in 1922. The 1922 volume contained seven articles on some phase of dry milk. Oddly enough, it wasn't until 1946 that another volume contained so many. The proceedings of the 1923 World's Dairy Congress contained seven articles about dry milk. Included was one by Supplee describing the relationship between the moisture content of dry milk and the development of stale flavors. Articles by Supplee and by Holm and Greenbank also laid the foundations for our present knowledge of the factors influencing the oxidation of fat in dry whole milk. These were the first of many articles dealing with the stale and tallowy flavors. Effective control of oxidation in dry whole milk became possible with the disclosure of methods for gas-packing by Merrell and Schibsted *(8)*. Vacuum and gas-packing had been suggested earlier *(5)* but did not prove effective, doubtless because a sufficiently low oxygen level was not attained.

Uses of Dry Milk Solids

The industry early recognized the fact that nonfat dry milk solids from all sources did not produce the same results in breadmaking. Systematic study of this problem started with the work of Skovholt and Bailey *(9)*, who showed that nonfat dry milk solids from unheated skimmilk not only depress loaf volume but also cause slackness and extreme extensibility of the dough. The heat-labile factor still is not positively identified, but the facts about how to process milk for breadmaking are well known. Expansion in the use of nonfat dry milk solids has necessitated the manufacture of nonfat dry milk solids for specific end uses. Grade designations still do not recognize end use, but it seems only a matter of time until this becomes necessary.

The successful merchandising of nonfat dry milk solids for household consumption is one of the brightest spots in the industry. Sales have increased from 2.4 million pounds in 1948 to nearly 120 million pounds in 1954. There is every prospect that, ultimately, this will be the largest market for nonfat dry milk solids. This became all the more possible with the introduction of "instant" nonfat dry milk solids. Difficulty of redispersion in water was recognized almost from the start as one of the limiting factors in the use of dry milk. The production of instant nonfat dry milk solids has been one of the greatest research accomplishments of the industry. After the introduction of instant nonfat dry milk solids by the Carnation Company in 1954, many other companies have succeeded in manufacturing products with similar dispersibility characteristics. Whether someone will succeed in producing an instant dry whole milk is still a question. This might go far toward gaining household acceptance of dry whole milk in this country. The suggestion was made more than 30 years ago by Blackham *(2)* that it

might be cheaper to dry all milk and distribute it in powder than to attempt to continue our present methods of distribution. The suggestion is still not without some merit. The dry milk industry today is large and thriving. Wider usage may depend upon how well the industry solves its problems.

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By-Products Manufacture

Progress with Changing Times

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The by-products of the dairy manufacturing industry are skimmilk, buttermilk, and whey. These are residues from the manufacture of cream, butter, and cheese. Many different kinds of animal feeds, chemicals, and especially food products are now manufactured with the basic by-products as raw materials. This was not done 50 years ago. Our manufacturing technology did not then extend to utilization of by-products. Nor was the nutritional value of milk by-products recognized; sanitation, processing, and storage facilities were not suitable for converting by-products into human food.

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Modern technology and advances on many scientific fronts have led to a reappraisal of the value of skimmilk, buttermilk, and whey. Research has shown that these constituents are highly nutritious and that, by proper processing and handling, their nutritive value and food appeal for both man and animals can be increased. Although 50 years ago most of the milk by-products were poorly utilized. even today only about 60% of the protein and lactose produced in cow's milk is consumed as food. The remainder (approximately 1.5 billion pounds of milk protein and 2.5 billion pounds of milk sugar) is fed to animals as skimmilk, buttermilk, and whey; or to a lesser extent, it is manufactured into industrial products; or it is run to waste. Since the protein and lactose comprise two-thirds of the solids of milk, and since about 40% of the production of these constituents is not now used for food, the industry must continue progress toward better utilization.

Efficient usage of by-products is increasing. Wisconsin, the greatest whey-producing state, discarded or fed all its whey to animals in 1906. By 1935 only 0.4% of its whey was manufactured and this mostly as dried whey. In 1953, 29% of the annual production of 5.8 billion pounds was made into lactose, condensed whey, or dried whey. The remaining two-thirds of production was still largely returned to farms.

Improved utilization of skimmilk in Wisconsin has occurred since the time when all of it remained on farms at the beginning of the century. By 1937 half of the skimmilk was kept on farms for livestock, and in 1953 only 4% of Wisconsin's skimmilk remained on the farm.

By-Product Production

Production figures were not gathered in 1906 but, from the "Census of Manufacturers" taken in 1904, the production can be estimated as follows:

	million lb.
Buttermilk	747
Whey	2,854
Skimmilk sold	1,161
Casein	12

Fifty years later production of by-products had greatly increased in quantity, quality, and variety. Some values are shown in Table 1.

TABLE 1

Manufactured by-products—1954[a]

	million lb.
Buttermilk (estimated total)	2,000
Whey (estimated total)	16,000
Condensed whey	175
Dried whey	175
Skimmilk	
Unsweetened condensed	637
Sweetened condensed	101
Evaporated skim	17
Nonfat dry milk solids	1,402
Skimmilk for animal feed	19
Casein	5
Malted milk powder	31
Milk sugar, crude	32
Full-skim American-type cheese	0.4
Cottage cheese	
Curd	434
Creamed	535

[a] Values derived from reports by Agricultural Marketing Service, USDA Statistical Bull. 167, October, 1955.

At the turn of the century, many dairy farmers were separating their milk to sell the cream to butter factories. Only the producers near a crossroads cheese plant or close to an urban area could find a market for fluid milk. Skimmilk from the creaming operation usually went to farm animals, and the whey from the cheese plant was discarded into nearby streams or was sometimes fed to pigs. The cheese factory's whey tank, which was apparent to the farmer by its odor long before he drew his wagon alongside of it to refill his milk cans, has disappeared. Special cans must now be used for whey if indeed the producer cares to take the whey at all.

Modern centralization of production in larger and larger plants, due to tank-truck pickup, now relieves the farmer from separating his milk. It improves the quality of milk received

by the factory, and increases the size and efficiency of the manufacturing operations by concentrating skimmilk, buttermilk, and whey in utilizable quantities in one location. The largest cheese factories produce up to one million pounds of whey per day, and some milk-drying plants have about half this quantity of skimmilk to process during peak production.

Processing Equipment

Startling changes in the facilities for manufacturing by-products have occurred during the last half-century. Developments in metallurgy have provided sanitary, corrosion-resistant stainless steel in place of the flavor-tainting copper formerly universally used.

Centrifugal separators are used to recover fat from milk to produce skimmilk of about 0.03% fat, from cheese whey to reduce the fat from 0.3% to 0.03%, and from sweet-cream buttermilk to lower the fat from about 0.7% to 0.3%. Such excellent recoveries have not always been possible. At the start of this century farmers were abandoning the old shallow pan gravity-separation method of obtaining marketable cream from their milk in favor of the new mechanical separators. Since the gravity system probably yielded only 50 to 75% of the fat as cream, the new centrifugal method of skimming 80 to 90% of the available cream was a marked improvement. The hand-operated separator of 1906 was sold to farmers and the skimmilk stayed on the farm for animal feed. Today the farmer does not buy a separator. His milk is separated in a large central plant by an electrically operated machine with a capacity as high as 11,000 lb. per hour and with a recovery of 99.9% of the fat.

Processing operations must be centered around water removal from raw by-products to preserve them and make them suitable for food, feed, or industrial uses. The concentrating and drying equipment needed to remove most of the 90-95% water in whey, skimmilk, and buttermilk has evolved to a high state of perfection.

One hundred years ago, Gail Borden developed his process for condensing milk under vacuum to maintain quality and flavor. In 1900, the simple single-effect evaporating pan was used throughout the condensed milk industry. In the last 25 years (with large volumes of whey and skimmilk to concentrate) the batch pan has been replaced by rapid-circulation evaporators of double, triple, or even quadruple effect. These evaporators have several advantages over the old single-effect pans. They decrease the cost of water removal, operate at a high rate of evaporation, provide efficient protection against heat damage to the product, and operate with a minimum of entrainment losses. The large installations are usually operated on a continuous basis.

Dried milk, mentioned in the 13th century by Marco Polo, remained undeveloped as a useful article of commerce until early in the 20th century. Then, intense interest in processing equipment led to rapid advances in the spray and roller drying of skimmilk.

The year 1906 saw the birth of the first highly successful commercial enterprise for spray drying: the Merrell-Soule process. Attempts had been made to spray dry fluids since 1872, but the basic contribution of the Merrell-Soule Company was to concentrate the milk in a vacuum pan before spraying it. The Merrell-Soule drier was a box-type drier in which the dried product settled to the bottom of the drying chamber.

A few years later, 1913-21, C. E. Gray and A. Jensen developed the Gray-Jensen drier, which was especially suited to the drying of skimmilk. This drier was equipped with a concentrator or wet collector in which the outgoing air was stripped of its residual powder by a spray of incoming skimmilk. The drying chamber was circular and the cyclonic path of the air was countercurrent to that of the incoming spray. In 1917, C. E. Rogers patented the first of a series of box-type driers, which were to occupy an important place in the dry milk industry.

Modern driers have evolved from these basic designs. Today the product is usually concentrated under vacuum and sprayed into a cylindrical or rectangular-shaped chamber where drying occurs almost instantly. The powder is quickly separated from the moist, hot air by different types of collector systems.

The first successful attempt to dry milk on hot steel rolls was made about 50 years ago, when the Just and Hatmaker interests were united to produce a process widely used in the United States today. Skimmilk, whey, and buttermilk are still dried on atmospheric double drums that closely resemble the original Just-Hatmaker equipment. Over the intervening years, many modifications have been tried. The drums were placed in a vacuum chamber to lower the drying temperature and produce a more soluble powder. Because this equipment was expensive to install, difficult to maintain, and costly to operate, few if any vacuum drum driers are still dehydrating milk by-products. About 1940, one set of double rolls was placed above another, the extra rolls being used either as a pre-drier or as cooling rolls. The arrangement was helpful in drying whey.

The dairy industries supply group has added many "fringe benefits" to the basic equipment for separating, condensing, and drying by-products. Tank trucks now haul milk to centralize it in large plants where it can be efficiently processed. This is changing butter, cheese, and milk-powder manufacture from small to increasingly larger units. By-products, being available in quantities up to a million pounds daily, can thus be subjected to cost-saving manufacturing processes.

Natural ice was widely used at the turn of the century. The farmer and the crossroads factory harvested it every winter for cooling milk products at winter's end. Now in place of ice water–cooling units and cracked ice with salt-freezing, there are small, trim, effortless compressors that reduce costs and save labor. Refrigeration, handling, and packaging machinery have improved products and widened their markets.

By-Product Manufacture

By-products that cannot be gainfully utilized must be discarded. Even this can now be costly in contrast to disposal to streams, practiced in the past. Waste disposal is presently a problem only with whey, for skimmilk and buttermilk are channeled to animal feed if no better use is available. Some cities are now charging about ½ cent per pound of whey solids for all whey discarded into the city system. The calculated costs for treating whey in a municipal sewage-treatment plant may vary widely. One estimate is 1.2 cents per pound of whey solids when high-rate filters are used, or 2.4 cents for activated sludge. If a cheese factory must build and operate its own disposal plant, costs will depend upon many factors with a range between 3 to 14 cents per pound of whey solids in the effluent. An inexpensive method for plant disposal is either lagooning, where soil and weather conditions are satisfactory, or spraying on land, when this can be done without creating a nuisance.

The sanitary handling of by-products has greatly improved over the years. Almost every plant has modern laboratory facilities and trained technicians. Pasteurization was practically unknown 50 years ago. Now the importance of pasteurizing and cooling skimmilk after separation or of whey after drainage from the cheese curd is recognized. Buttermilk, skimmilk, or whey neglected on the farm or in the factory is suitable only for animal feeds. But with careful treatment increasing quantities of these by-products are being processed into foods, pharmaceutical and industrial products, and superior animal feeds. This continuous upgrading is essential to create a situation that will make by-product manufacture economically attractive.

Plain and sweetened condensed skimmilk have been articles of commerce for almost a hundred years. A significant change in the texture of these products has occurred during the last half-century. The crystallizing habits of lactose have been learned, and sweetened condensed skimmilk can now be cooled, seeded, and stirred in a way that will encourage the growth of numerous crystals less than 12 microns in size. The concentrated skimmilks are made for, and used extensively in, food manufacture, particularly in the confectionery and baking industries.

Because of their highly perishable nature, skimmilk, whey, and buttermilk have been dried for food and feed. At the beginning of the century, no suitable drying methods were available, but with the passage of five decades many improvements have emerged. Ninety-one to 94% of the weight of these fluids is water, the removal of which has always cost so much that the recovered solids were relatively expensive for animal feed and even for human food. The cost of evaporating water to produce 1 lb. of by-product is about 2 to 2½ cents.

The heat treatment to which skimmilk is subjected has been found to have an important effect on the properties of the powder. After World War I, as increasing quantities of nonfat powder were used in bread, irregularities in dough behavior and in physical characteristics of the bread were noted. Then in 1927, workers in the Bureau of Dairy Industry showed that skimmilk heated to 190° F. before drying produced powder of improved baking quality. Two decades later, as dried nonfat milk gained a place in cottage-cheese manufacture, the need for powder from skimmilk heated to no higher than 160° F. was recognized. Today two types of dried nonfat milk are produced: high-heat powder for baking; and low-heat powder for cottage cheese, ice cream, and general use.

The newest development in the drying of skimmilk is the so-called "instant powder." This product when placed on cold water quickly wets and drops in small aggregates to the bottom of the container, dissolving en route with practically no stirring. The old type of powder was difficult to wet and required much stirring before it dissolved. The enhanced dispersibility of instant powder can be attributed to the large particle diameter which minimizes the tendency of the powder to ball-up in water. There are two basic processes for production of instant nonfat dry milk: *(a)* agglomeration of preformed particles and *(b)* spray drying to produce large single particles and/or aggregates. For the agglomeration process, previously dried skimmilk is wetted to levels above 8% moisture to cause the particles to stick together. In this procedure, the dough-like aggregates are held for a short period for the lactose to crystallize partly, then they are redried (Peebles' process). This process must be conducted within certain time, temperature, and moisture limits if a soluble and flavorful product is to be obtained. Exposure of the particles to excessive moisture or heat results in insolubility and off-flavors. Powder thus held for the lactose to crystallize, when redried, is in the form of nonhygroscopic agglomerates. Another agglomerating procedure requires the moistening of plain powder while it is pneumatically conveyed in a water-vapor stream. After the particles collide and stick together, the agglomerates are redried. Agglomeration in this way does not afford the lactose an opportunity to crystallize; hence the powder is hygroscopic.

The second method of producing instant powder is to cause the milk to dry as very large particles so that later agglomeration will not be needed to give instant solubility. One recently designed drier introduces the spray into the incoming air, where the high turbulence is said to cause the partially dried spherical particles to stick together to form aggregates during the drying process. Conventional spray driers produce particles that vary in size from about 15 to 60 microns. Agglomeration of these produces aggregates up to and even exceeding 300 microns. If skimmilk of 48% solids content is sprayed by special nozzle to get coarse atomization, an instant powder with a particle size of 30 to 100 microns is formed.

Instant powders have thus far been produced only for household use. Their advantages for most commercial uses are still obscure.

Whey is more difficult to dry than skimmilk because 75% of its solids is lactose, which dries as an amorphous sirup unless special processes are used. Advancement in the drying of whey came rapidly during the decade 1930-1940. Three general methods were developed. The Simmons process of tunnel-drying whey for animal feed consisted of concentration under vacuum to 70% solids, seeding and holding to crystallize the lactose, further drying, and grinding. Drum drying, so easily applied to skimmilk, was difficult to adapt to whey. But with various modifications to the drums or to the whey, workable processes were evolved. Spray drying produces the best grade of whey powder. The high concentration of lactose and the hygroscopic nature of spray-dried whey causes it to stick in collection systems, so there has been much patent activity directed toward inducing lactose crystallization before or during drying. In the last 35 years, the engineering contributions of David Peebles toward improved evaporation and drying processes for whey did much to make whey processing a big business.

The roll drying of sour-cream buttermilk grew with the feed shortage caused by World War I. Recognition of the value of buttermilk as an animal feed continued after the war and today drum-dried, neutralized-cream buttermilk is highly valued as a hog, poultry, and calf feed. The product is rather difficult to dry because it tends to "whey-off" and form a sticky, nonhomogeneous, brown smear on the hot rolls. Vigorous agitation and uniform application of the milk film on properly adjusted drums will avoid trouble.

Sweet-cream buttermilk may be roll or spray dried. This product has grown in importance in the last quarter-century, and especially since World War II, because of its excellent flavor and emulsifying properties when used in milk chocolate and in ice cream mixes. Dried buttermilks contain about 5% fat, and the sweet cream product, used mostly for human food, must be so handled that fat deterioration is retarded. Since it does not keep as well as dried whole milk, it must be used soon after drying or held in cool storage.

Products from By-Products

Whereas there was practically no by-product manufacture 50 years ago, today three major groups of products are produced from skimmilk, buttermilk, and whey. These groups are: animal feeds, chemicals, and foods.

Animals have always consumed a large portion of dairy by-products, but until recent years no attempt was made to process these materials into improved feeds. Condensing and drying came first, then more valuable fractions of the liquids were recovered for food or industrial use, and finally processing of the residues has upgraded the feed itself. Mixed feeds can be materially improved by the addition of 3 to 5% whey solids. Whey itself must be fed sparingly, since the 75% lactose it contains may cause scouring in animals. Three methods of manufacturing whey feeds are now being used to avoid this difficulty and to increase the nutritive value of whey:

1. About half of the lactose is "skimmed" off by condensing the whey, allowing the lactose to crystallize, and centrifugally removing it, leaving as feed the low lactose residue. The protein itself may be heat-coagulated from whey and removed for animal feed. These processes are part of procedures for lactose manufacture.

2. The lactose is hydrolyzed to glucose, galactose, and incidentally formed oligosaccharides by treatment with the enzyme lactase. The latter is prepared by culturing a lactase-producing yeast in the whey itself. Hydrolyzed whey has more nutritive value and is more palatable to the animal than untreated whey.

3. Fermentations of various kinds have recently been developed by using the lactose in whey as the fermentable carbohydrate. By this means, various vitamins, protein, and even fat can be produced in the whey feed product. There must be economic justification for any chosen procedure. The lactose also may be fermented to alcohol, which in turn can be generated to vinegar. The residues, being high in protein and other nutritive factors, are excellent animal feed supplements.

Skimmilk is increasing in importance as a raw material for foods so that its use in feed is rapidly declining. But, after the period early in the century when most skimmilk went to animals, a process for manufacturing concentrated sour skimmilk was patented (L. A. Rogers, 1923). About 2% acid was developed by use of a culture, and the product was concentrated to a third of its weight, at which point the 6% acid it contained preserved it. Condensed or semi-solid buttermilk is still made from neutralized-cream buttermilk for animal feed in much the same way.

Chemicals made from milk at the turn of the century were casein, lactose, lactic acid, and denatured whey-protein preparatioins. The processes for producing these have been improved and many new products have been developed. Casein can now be made in a continuous machine, where acid is added, curd precipitated, the whey drained off, and the curd washed and dried.

Calcium, sodium, and potassium caseinates are prepared for use in food and industrial products. Extraction of casein with methanol produces a vitamin-free protein for nutritional studies. Both casein and whey protein are now hydrolyzed by enzyme or acid to make protein hydrolyzates useful in commercial bulk fermentations and microbiological nutrients. The hydrolyzates are sources of amino acids, but these are difficult to separate one from the other. Both tyrosine and tryptophane have been commercially produced in pure form from milk protein.

Methods for manufacturing lactose have been changed little in 50 years, but engineering improvements have increased efficiency and made it easier and cheaper to make a pure sugar. However, the demand for milk sugar has fluctuated widely. Its limited use prior to World War II was in chemicals and pharmaceuticals. The discovery of penicillin quickly created a demand for lactose as the preferred carbohydrate in fermentation media. Lactose production jumped from 10 million pounds in 1944 to 22 million pounds in 1945 and 50 million pounds in 1951. The constant urge to lower costs has led to development of methods for using cheap dextrose for the penicillin fermentation. This is presently causing a rapid drop in demand, production, and price of lactose. Production in 1954 was at 32 million pounds.

Lactic acid and calcium lactate are now made from whey by improved processes that have required years of laboratory research and commercial experience to perfect. A *B. bulgaricus* culture is used to convert lactose to lactic acid efficiently. The acid is intermittently neutralized to avoid stoppage of growth of the organism, and the product is recovered as calcium lactate by concentration and crystallization. To produce lactic acid, the calcium lactate is treated with sulfuric acid to precipitate calcium sulfate, which is removed by filtration.

Food manufacture is the most promising outlet for profitable utilization of dairy by-products. Except for cheese products, present uses were undeveloped and all but unknown 50 years ago. Whey and skimmilk cheeses, including a crude form of cottage cheese, had long been made, but the extensive and improved usage of by-products in bakery goods, confections, meat compositions, and specialty items is an advance produced by modern technology.

Rapid expansion in production of ice cream, ice milk, sherbet, and soft-frozen products has been a factor in by-product utilization. The Mellorine-type, vegetable-fat desserts are providing a new outlet for nonfat milk. Another solution to the problem of providing a low-cost frozen product is the current trend toward high-grade ice milks. An ice milk containing 4% fat and 13% nonfat milk solids is nonfattening, low in cost, flavorful, and attractive, and is an excellent outlet for skimmilk.

Sweet-cream buttermilk is now a recognized source of milk solids for ice cream and for chocolate products. The milk fat present in buttermilk, being difficult to remove, is usually available at a lower price than the fat in cream. However, the decline in butter production and the cost of getting the buttermilk to centers of ice cream or chocolate manufacture have limited practical usage.

Fluid cheese whey used to replace the water in sherbet contributes milk flavor and even lactic acid as an acidifying agent when there has been adequate fermentation control. Condensed or dried whey is also suitable for sherbets, but its use is harder to justify economically than the fluid product when the latter is readily available. Whey has been advocated for use in ice cream and ice milk and, under controlled conditions, it should have a place in these products.

Cultured buttermilk was practically unknown in the United States at the beginning of this century, although it had been used in various crude forms in Europe during the last hundred years. It is now providing a substantial outlet for skimmilk because of its excellent body and flavor. Quality in cultured buttermilk is a result of constant attention to starter propagation and manufacturing technology. Another beverage, chocolate drink, made with skimmilk and some fat was developed into an important item in the market milk family a quarter of a century ago.

Cottage cheese has been the most popular by-product cheese made in this country. It has been developed from a mass of sour cooked curd, home-made by most of our grandparents, to an attractive, flavorful cheese manufactured under strict scientific control. The curd is formed in pasteurized skimmilk by rennet and acid produced during controlled starter growth. Cottage cheese is perishable; it must be made under strictly sanitary conditions and always kept under refrigeration if it is to have the shelf life expected of our modern marketing system. Pot and baker's cheese, like cottage cheese, are soft skimmilk cheeses used largely in food manufacture.

The whey cheeses, traditionally popular in the Scandinavian countries, have had less appeal in America. Ricotta (principally whey protein) and mysost or primost (containing all the whey solids) have changed but little in manufacturing methods or usage during the last 50 years. Whey and/or skimmilk is used in cheese spreads to the extent of 5-10% whey solids and 25-30% nonfat milk solids.

Bakers and confectioners depend upon milk by-products for improvement in flavor, physical characteristics, and nutritive value of their goods. The dairy industry in turn has developed processing methods and forms of dairy products especially adapted to use in these foods. For 25 years, the baker has been the dried milk manufacturer's best customer. The confectioner has preferred plain or sweetened condensed milks, although he too is now using much of the dried product. An average of 3% of the weight of the flour is milk solids in our national loaf of bread. The milk imparts a golden brown crust color, improved volume and texture, and superior flavor and food value. Buttermilk and whey can be used in bread, but whey is especially adapted to sweet goods, where it contributes color, flavor, and a soft cake-like texture.

Confections have been made for hundreds of years but it is our modern technology, our economic production, and control of quality ingredients that have made them the popular products they are today. The casein of skimmilk is essential for giving caramels a firm, chewy body. Both skimmilk and whey improve the flavor and physical characteristics of fudge. Whey, with its high lactose content, is especially useful in fudge, to which it contributes a crystalline structure. Vegetable proteins and various carbohydrates are used in candy, and these have at times replaced the milk constituents. It has never been possible for a vegetable substitute to equal the fine flavor produced by a milk product during the cooking of caramel, fudge, and chocolate mixtures. Sweetened condensed skimmilk is sometimes used in chewing gum to improve flavor and chewing characteristics.

Meat formulations such as frankfurters, liverwurst, sausage, and meat loaf may contain up to 3½% by weight of cereal, starch, or nonfat milk solids. These ingredients bind water and improve the physical properties of the finished material. Milk products also contribute toward a full, pleasing flavor.

By-products of milk are now used in many proprietary foods where they usually function to improve flavor and body. Both milk and whey are useful in the preparation of canned cream-style soups. Whey is of special interest because of its compatibility with acids such as that of tomato. Skimmilk and cooked potato, when whipped, dried, and toasted, produce a flavorful wafer. Casein, fish, and a starch make a tasty fish chip when properly mixed, dried, and fried in fat. Skimmilk is an important ingredient in some prepared pudding powders, and whey has been a part of a canned fruit pudding. Whey protein was processed in Europe during World War II to make an egg-white substitute. It has been used as a whipping agent in salad dressing. There have been attempts to prepare whey beer and whey wine. Vinegar has been produced from whey commercially in this country for some years. Margarine oil is churned in skimmilk to give the margarine a milk-like flavor. Low-salt fat-free milk is now produced in "instant" dry form for special low-sodium diets.

Skimmilk combined with vegetable fat is serving as a "milk" base for a growing list of substitute items. These can be sold at a lower price than products made with milk fat. "Mellorine" has already been mentioned. Filled evaporated milks are made with vegetable oil; however, it is a violation of federal law to transport these items across state lines. Proprietary infant foods, both dry and evaporated, are made with a blend of vegetable fats and skimmilk, but since they are sold in drug stores as special dietary items interstate shipment is permitted.

These are examples of the many new ways of using milk by-products in manufactured foods. For the most part, they have been developed through technological research during the last quarter-century. By-products are not only improving nutrition; they are contributing to the enjoyment derived from eating foods superior in flavor, body, and texture.

Trends for the Future

The future of by-product processing would be difficult to predict. No attempt will be made to visualize conditions 50 years from now, but it may be useful to speculate on the outlook for by-product utilization immediately ahead. There is no lack of new and good uses for skimmilk, whey, and buttermilk; there is great need of economically sound uses by which a manufacturer can realize a reasonable profit on his venture. Pharmaceuticals or chemicals with unique characteristics are profitable, but the supply of by-products is much larger than is needed to manufacture the required items. Feeds and foods remain as the largest potential outlet but here, too, competing materials push for a share of the market at marginal prices. It is clear that by-product utilization today is deeply involved in economic problems.

Two constituents, the protein and the lactose, should receive first consideration in all by-product disposal plans. The milk salts and the array of water-soluble vitamins, although nutritionally important, are usually passed over lightly as being factors "also present" in foods or feeds made from by-products. The intangible whey factors, hitherto scarcely recognized in skimmilk and whey feeds, are coming to command economic consideration. These "plus" elements of whey should enjoy a distinct nutritional position for as long a time as the "synthetics" do not encroach on their uniqueness.

Strenuous efforts are being made today to increase the protein content of many human diets and animal feeds. Milk protein is recognized as being of the highest nutritional quality. Because it is of bland and pleasing flavor in

contrast to some of its rising vegetable competitors, it should maintain its position in foods and feeds. But here too, as with butter vs. margarine, vigorous competition between the milk and vegetable proteins for the food market can be predicted. Meanwhile, skimmilk and buttermilk are excellent inexpensive sources of protein. More highly concentrated preparations are the caseins and whey proteins tailored to fill special needs where whipping, viscosity, body, water-holding capacity, or buffer action is required. The trend toward manufacturing milk-protein products to fill specified requirements will probably increase with the advancing science of food technology.

The future for lactose may well depend upon the gathering of more nutritional data to justify its use per se in foods. The lactose normally present in natural milk products is nutritionally desirable and relatively inexpensive. More costly and of less apparent significance is lactose added to food as a carbohydrate in competition with sucrose or glucose. Many derivatives of lactose can be made, but few of them possess unique properties which might enable them to be competitive with derivatives of other carbohydrates. The limited solubility of lactose and its stability in acid media offer interesting possibilities in need of exploration. Useful fermentations that employ lactose in preference to other carbohydrates are rare. Even the penicillium group, which is native to lactose, is being adapted to glucose. The task of finding uses for lactose is in part an economic one in which milk sugar is at a serious disadvantage compared to the cheaper carbohydrates. Whether very large scale production could result in putting lactose within the price range of other sugars is questionable. The best solution for disposal of the huge quantities of lactose now wasted appears to be to process much of it with the other constituents of whey or skimmilk into superior foods or feeds. Processes to do this are usually lower in cost than the concentration and crystallization processes needed to recover the sugar itself.

Fifty Years of Progress in Dairy Plant Engineering

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Dairy plant engineering in the year 1905 was simple as compared to 1955. The industry in this country was characterized by having many small plants located in buildings that often were not much better than sheds, although there were some rather large butter centralizer plants, which were well organized and finely built. The processing equipment in all plants was rather simple and most of the operations were controlled by hand. The refrigeration systems and cold-storage rooms were the most expensive mechanical parts of the plant. There were very few milk plants and ice cream plants. The emphasis was on butter and cheese making and to a certain extent on evaporated milk manufacture. The comfort of the operator and sanitation for the product were given relatively little attention, by present-day standards.

A. W. Farrall

During the period immediately after World War I and for the next 15 years tremendous progress was made in both building construction and machinery, leading to the beautiful and efficiently designed plants and equipment that are found in the industry today.

Dairy Plant Building Materials

Improvements in building materials have resulted in wooden structures being replaced almost entirely by buildings of concrete, ceramic tile, or metal. Previous to 1920, most of the floors in dairy plants were made of plain concrete. Then terrazzo was widely used for a few years; however, it was early found that floor tile, such as had been developed in the packing house industry, was more satisfactory. Since 1935 many floors have been constructed of concrete imbedded with hard emery aggregate, which provides a long-wearing and nonslip surface.

Improvements in dairy walls also have been made. As early as 1925, many of the dairy plants were built with tile walls in their processing rooms. About this time paint such as "barreled sunlight" started a new trend in longer wearing wall surfaces. In the thirties, paints were developed that were still more resistant to moisture and could even be applied with considerable success to a wall that was not entirely dry. This was very advantageous in a plant that could not be shut down for repair. Since 1940, many plants have made use of stainless steel for kick-plates on doors and for trimming around windows and doors.

General improvements in ventilation and the elimination of excessive moisture in processing rooms have greatly improved working conditions and have increased the life of dairy equipment and interior surfaces.

Steam Plants

In 1905, as now, steam plants in the dairy processing factories were of great importance. They furnished heat and supplied power for driving the machinery by means of a line-shaft and belt arrangement. In the smaller plants vertical boilers were commonly used, but in the larger plants very efficient boilers of high pressure horizontal return tubular design were used. Usually the fuel was coal. All boilers were hand-fired and required constant attention. Very little consideration was given to the treatment of the feed water, and as a result boiler maintenance was a problem. About 1919, considerable interest was manifested in the use of oil or gas for fuel in dairies, although for many years coal continued to be the standard fuel. The development in 1929 of automatic stokers was a great boon to the small and medium sized dairy plants. About 1938, several so-called automatic boilers came on the market and these are now widely used.

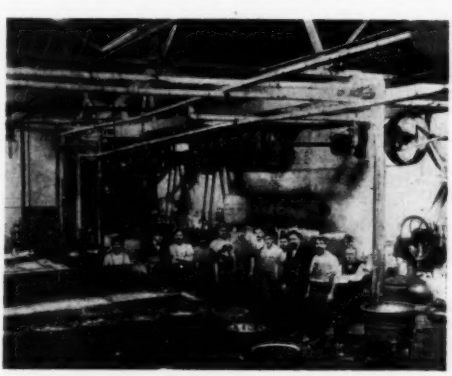

Fig. 1. A typical ice cream factory at the turn of the century. This is the J. M. Horton Co. of Brooklyn, N. Y. in 1898.

The treatment of feed water became important as the steam requirements of the dairy plant increased with the addition of mechanical can washers, bottle washers, pasteurizers, and the like. The advent of the Zeolite water softener, which came into general use about 1925, greatly reduced the problem of taking care of

a boiler and at the same time improved the washing and heating efficiency of the dairy plant. Many of the steam piping systems, before the twenties, did not use insulation. However, as fuel became more expensive and the uses greater, most plants installed efficient coverings for pipe lines and also, where possible, made arrangements to return condensate to the boiler for re-use.

Refrigeration

Many dairy plants of 1905 used ice and salt brine for refrigeration. This was particularly true in the northern states where natural ice was available. The ammonia compression system was commonly used, however, in large plants. Improvements were constantly being made in refrigeration machinery. The early-day compressors were extremely large and cumbersome and of very slow speed. At about the time of World War I, the speed of ammonia compressors was increased, with a resulting saving in floor space and also in materials for construction. Ammonia was the universal refrigerant. The brine system of refrigeration was practically universally used for cooling milk products, and many of the cold storage rooms also were cooled with this system. About 1920, considerable progress was made in controls for direct expansion systems and most plants after that period made wide use of this method. It was commonly applied to milk and cream coolers and processing equipment by 1930. However, in many plants direct expansion was replaced later by the "sweet water" system, which was best adapted for use with the stainless steel plate heat exchangers, which became available about 1930. Using water at 32° to 34° F. the "sweet water" system eliminated the danger of freezing milk onto the coolers. It also largely eliminated the corrosion problem, which otherwise would have been encountered in running brine through stainless steel heat exchangers. With the development of reliable electric controls automatic operation of refrigeration systems became common for both cold storage rooms and milk cooling equipment.

The flooded system of refrigeration, which was developed about 1925, is of particular interest. It greatly increased the efficiency of cooling equipment, particularly milk and cream coolers and ice cream freezers.

One very significant development of the early twenties was the design and widespread use of the small fractional horsepower refrigeration machines for household refrigerators. Similar equipment was adapted to ice cream cabinets and milk coolers. This development revolutionized the storage and vending of ice cream, since it eliminated the costly and messy ice and salt cabinets. In many instances this same system was used to cool motor trucks used in distributing the product. Most of these small machines originally were designed to use sulfur dioxide or methyl chloride. However, Freon, which was developed about 1926, gradually became almost universally used in small refrigeration equipment and even in large equipment in some cities, where it is required today on account of the safety hazard from ammonia.

About 1926 a great effort was made to eliminate the use of ice and salt with its attendant problems of corrosion, cost, and labor. The so-called cold can type of refrigeration system was widely used for about 10 years. With this system cartridges containing a eutectic solution were placed in hardening rooms and frozen, then withdrawn and placed in trucks or cabinets to provide refrigeration for a number of hours. Great improvement was made also in the use of cold plates for cooling truck bodies.

The expanding ice cream industry with its resultant demand for large amounts of refrigeration, particularly at low temperatures as required by large hardening rooms and by continuous ice cream freezers, resulted in a demand for the two-stage refrigeration system. By 1940 a good many plants were using the method, since it allowed much higher efficiency for low-temperature refrigeration without sacrificing efficiency on the high temperature load. For combination milk and ice cream plants the system was particularly useful and adaptable. The advent of the continuous ice cream freezer resulted in the development of improved oil-removing devices for refrigeration systems, since it was found that many of the troubles with the first continuous freezers were caused by excessive oil.

About 1945, refrigeration machine manufacturers developed the new multiple-cylinder, high-speed ammonia compressors constructed along automotive engine lines. These machines greatly reduced the space and the amount of material required for refrigeration machinery. Servicing and repair of these machines was much more easily accomplished.

Many cold storage rooms of 1905 were insulated with sawdust and by air spaces. This gave way to the use of sheet cork, which was widely used by 1920. Even today cork is looked upon as a very efficient and satisfactory insulating material. However, it now has considerable competition from newer types of insulating materials, such as glass wool and foam plastic.

In the early twenties, attempts of dairymen to eliminate the nuisance of ice and salt led to the use of "dry ice," or solidified carbon dioxide. Equipment was developed for using dry ice to refrigerate ice cream cabinets, and particularly ice cream and milk delivery trucks. The difficulty of controlling temperatures properly so that ice cream, for example, would not become too hard has led to the replacement of most of this type of equipment with mechanically refrigerated units.

Pumping and Movement of Materials

The handling of milk products in a safe and sanitary manner has long been an important problem. In the early days milk was handled mostly in 10-gal. cans, although in some of the milk powder and evaporated milk plants ordinary iron pipes were used. Special rotary-type bronze pumps were widely used prior to 1920. Steam-driven piston-type pumps also were used. Special copper tubing coated with tin both inside and outside was used as milk conduits. Bronze fittings were used to connect the tubing. Previous to 1926, a number of manufacturers made pipe and fittings of different sizes and with different threads. The confusion and cost resulting from the lack of interchangeability finally became so great that the industry standardized on sizes of pipe and also on the use of Acme thread. This was a great step forward.

Much difficulty was encountered because of the pick-up of copper by the milk passing through the pipe, thereby causing off-flavors. This resulted in attempts to use stainless steel pipe and "white metal" fittings. About 1936, new stainless steel fittings were developed, which made possible a complete stainless steel system. For many years the problem of developing a satisfactory stainless steel positive pump remained unsolved. The sanitary, centrifugal-type pump was available in stainless steel as early as 1934. In order to eliminate the necessity for pumping, many plants attempted to use either the gravity system, pressure in tanks, or vacuum in tanks for moving dairy products through pipes.

The most recent improvements in pumping and conveying systems are probably the use of the O-ring type fittings on machines and stainless steel valves for pipe lines. The valves became available in 1939 and the O-rings in 1950.

The laborious and expensive process of handling milk cans, packages, and other material in the plant resulted in the development in the early thirties of special can and case conveyors. Since 1950, a number of plants have used the pallet system for handling bottle crates, packages of ice cream, and the like, with good results. The modern floor level conveyors and case-stacking machines are a major development in materials handling in the dairy.

In the early days the handling of the product before it reached the dairy plant involved the use of molasses pails, lard cans, and various other containers, but by 1910 the use of the 5-, 8-, or 10-gal. milk cans was almost universal. For many years the tinned-steel milk can has been the accepted container in the United States. In some European countries stainless steel cans and aluminum cans have been much in use since before World War II.

As early as 1910, large glass-lined tanks were used on railroad cars for hauling milk in bulk from receiving stations to milk plants. These tanks were replaced by stainless steel tanks. Perhaps the greatest development in this regard has been the almost universal adoption of the stainless steel insulated tank mounted on a truck. This development moved slowly in the late twenties but expanded rapidly during the thirties. The bulk system eliminated the great problem of sanitation and labor that was involved in handling 10-gal. cans full of milk.

Of most recent note is the bulk handling of milk between the farm and the plant. Bulk handling on the farm became popular in the large dairies of California as early as 1938. The advantages of the system were apparent, and by 1954, handling of milk on farms in tanks rather than in cans had become fairly widespread throughout the United States.

In contrast to the handling of milk in the bare iron or tinned copper pipes used in 1905, a good share of the milk in the modern plant is in contact only with stainless steel from the time it leaves the farmer's milk pail until it is bottled ready for delivery to the customer.

Machinery Drive and Control

Prior to about 1920, dairy plants were commonly fitted with line shafting with belt drives to the individual machines (See Figure 1). In most instances the line shaft was driven by a steam engine, although electric motor drive was becoming popular about 1919. The advent of the moisture-resistant, three-phase electric motor plus the greater emphasis upon plant sanitation caused a move toward direct electric drive on each individual machine. By 1930, practically all dairy plants used this system and had eliminated the belts and line shafts. Further refinements of the electrically-driven system involved development of waterproof electric switches and connections and automatic controls. In 1938, the triple A standards for electric motors for dairy plants were adopted. Perhaps one of the most important developments of the changeover to electrical drive has been automation.

Pasteurization, Cooling, and Storage

In 1909 only 25% of the milk sold in New York City was pasteurized. The problem of sanitizing dairy equipment was so great that President Roosevelt in 1907 appointed a commission to study the matter. This had the effect of spot-lighting the importance of sanitary design for dairy machinery and resulted in many improvements. In the early days coil-vat pasteurizers were universally used. These machines were usually made with a tinned copper coil mounted with a stuffing box at each end. The stuffing box was a constant source of contamination, and the problem of keeping the coil coated with tin was ever-present. The coil type vat was not much changed until about 1915, when the Jensen vertical coil vat was developed. This unit had the advantage of locating the stuffing box up above the product and out of contact with it. In 1939 a rotary seal was

adapted to the coil vat, thereby eliminating the stuffing box. Also about this time a method of constructing the coil out of stainless steel was developed.

The Farrington disk heater and cooler (Figure 2), developed by Professor Farrington of the University of Wisconsin, was much used

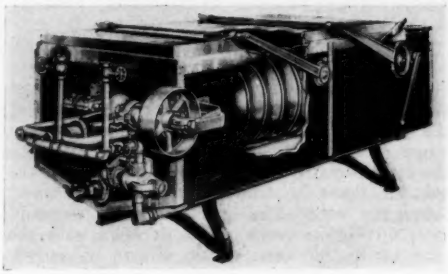

FIG. 2. An early style disk vat used for both heating and cooling milk and cream.

between 1906 and 1915. It was a continuous heating or cooling system, and from that standpoint it was an advantage. It was, however, difficult to clean and service.

The Jensen tubular heating and cooling system involving the use of a rotating cylinder inside a stationary cylinder, with the product in-between the two cylinders in an annular space, was a development of Aage Jensen, one of the pioneer dairy machinery manufacturers. This equipment was extensively used in the sour cream industry during the period 1915-25.

During the 1920's most of the milk was pasteurized in batch pasteurizers of either the coil-vat type or the continuous type consisting of pockets which were emptied and filled according to a program selector. One company developed a long flow-type holder which was widely used for a number of years.

Numerous attempts were made to perfect the flash system of pasteurizing before 1920. However, the problem of temperature control was not solved until about 1938 with the development of the plate heat exchanger and a special control valve which automatically by-passed any under-pasteurized milk back to the heater. This flow-diversion valve was one of the key developments in the progress of pasteurization and made possible the practical high-temperature, short-time method. The plate heat exchanger (Figure 3) was introduced into this country from England in 1929.

Of particular note is the improvement in pasteurizer construction resulting from a study made by the Chicago Health Department under the direction of the chief, Dr. Bundesen, and with George W. Putnam, now vice-president of the Creamery Package Manufacturing Co., as the research engineer. This study was made because it had been found that many pasteurizers were not operating efficiently and products

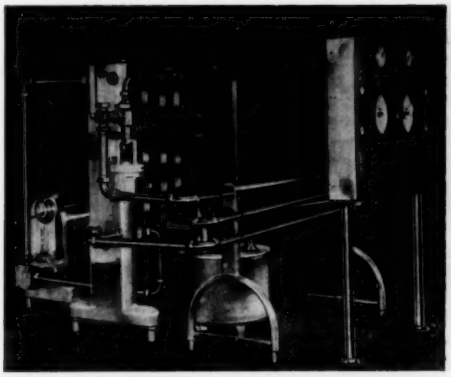

FIG. 3. A modern type pasteurizing and cooling unit.

were frequently improperly pasteurized. This work is classic and resulted in the development of such improvements as leak-detector valves, no-drip covers, and foam-heating devices. The U. S. Public Health Service was of great assistance in this study.

The claims made by different companies during the development of batch pasteurizers, relative to the efficiency of the spray method of heating as compared to the flooded method of heating, are of interest. Of interest also is the development of the extremely high-temperature pasteurizing systems used in connection with some of the milk powder processes. Milk was heated to a temperature of about 250° F. and instantaneously cooled by flashing it into a vacuum. This development took place about 1937. Another type of pasteurizer is the vacreator, which was developed in Australia and brought to this country about 1936. The principle of the unit is to rapidly heat the product to a high (185°-200° F.) temperature with steam and then flash it by two stages into a chamber with lower pressure in order to remove volatile odors. The process has been used considerably in connection with treatment of sour cream and also ice cream mix. The year 1955 brought forth new vacuum flavor removal and pasteurization equipment of simplified design.

In the cooling of dairy products 50 years ago, ice water or brine was the medium for carrying away the heat. The Farrington cooler, the horizontal coil vat, and later the vertical coil vat or the Jensen tubular heater and cooler system were all used successively for both heating and cooling. By 1920, the open surface type cooler with the top section cooled by water and the lower section cooled by brine was commonly used. About this time also, the double-tube cooler and heater was developed. It is still widely used today.

One interesting development of about 1930 was the cabinet cooler, which was a compact type of unit consisting of a number of surface

cooler sections housed together in such a manner as to provide a large amount of cooling surface in one piece of equipment and occupying a small area. This cooler in several modified forms was built principally by the Cherry-Burrell Corp. and Mojonnier Brothers. Since the development of the plate heat exchanger, this cabinet type cooler is not used as much as previously, although many units are still in operation.

About 1927, many attempts were made to develop direct expansion sections for coolers; however, the problem of accurate temperature control was very difficult to solve. The use of the sweet water cooling system with either a cabinet cooler or plate heat exchanger has been found in most instances to be much better. In small plants the vat type pasteurizer and cooler is still commonly used, particularly for heating. A small surface-type cooler is used for quick cooling.

In the period from 1905 to 1920, it was customary to store milk in vats or in milk cans. However, in the twenties, the industry began to use large specially made glass-lined storage tanks having a capacity of 1,000 gal. or more. Usually these were of round horizontal or vertical design and had no provision for either heating or cooling but were fitted with a certain amount of insulation. As stainless steel came more into use, storage tanks were constructed of this metal and often in rather large sizes, such as 2,000 or 3,000 gal. per unit (Figure 4).

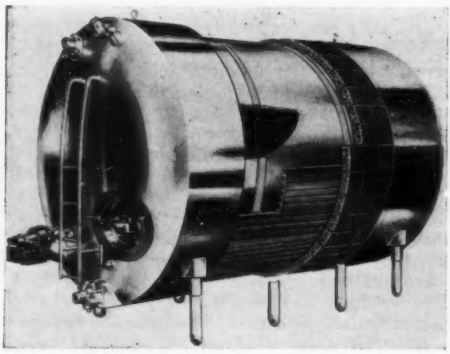

FIG. 4. Modern milk storage vats are made of stainless steel inside and out and have insulated walls.

About 1940, these tanks were constructed with a direct expansion refrigerated section in the bottom so they could be used to do a small amount of cooling if the milk needed to be brought down a few degrees in temperature.

Today these tanks are built according to specific sanitary standards with no sharp corners and with provision for agitation. Since 1945, some plants have used air pressure to agitate the milk in these storage tanks.

Churning

In 1905 churns were made of wood. Usually these were fitted with wooden rolls, and in some instances special equipment was devised for unloading the butter from the churn barrel. The churns were usually belt-driven and had open gears and a clutch with several speeds. There was practically no way of thoroughly cleaning them.

This system of churning butter continued until about 1927, at which time the Jensen metal churn, providing a revolutionary new method, was introduced. This churn, built in the form of a rotating cube, had no internal moving parts and no stuffing boxes. Although the Jensen churn obtained some popularity, the wooden churn continued to be the one most commonly used. The next important development in churns came about in 1933 with the introduction of the roll-less churn. This was made of wood but had some advantage from the sanitary standpoint in that there were no stuffing boxes. Several companies made different designs of this type of churn, and by 1940 very few roll-type churns were being sold.

At this time much attention was being given by the major companies to the development of a continuous-type churn. Several experimental machines were in use in the United States by 1945, and machines developed by the Swedes and by the Germans were in operation by 1949 on a limited commercial basis. The economic situation in the butter industry has not been conducive to expenditure of the amount of money necessary to buy these machines, however, and their use is still limited.

In the butter industry, remarkable improvements have been made in automatic butter printing and packaging equipment. The Doering butter cutter, brought out in 1925, was a great boon to the industry. The automatic printing and wrapping machines developed in 1935 have also been of great importance from a labor-saving standpoint.

Freezing of Ice Cream

The ice cream industry was just beginning to unfold in 1905. The vertical tub freezer with ice and salt as the refrigerant was universally used. (See Figure 1.) Experiments were conducted from 1907 to 1909 by Mr. Valerius of the Creamery Package Manufacturing Co., with a continuous freezer, which was built along the general lines of the Farrington disk heaters and disk coolers. Many of these machines were sold and used throughout the country until about 1915, at which time the industry began to use the horizontal brine-type freezer on a large scale. By 1920 the ice cream business had grown so much that in the large cities many plants had batteries of 20 to 30 horizontal brine-type freezers. (See Figure 5.) These freezers of 40 to 100 qt. capacity were an impressive sight. They turned out a tremendous volume of ice cream and helped to build a great industry.

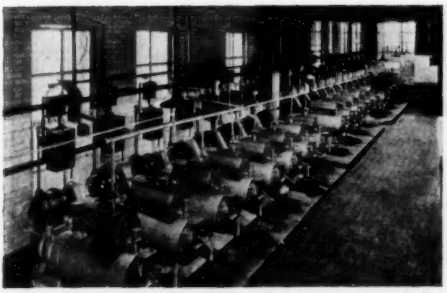

FIG. 5. A post World War I plant equipped for mass production.

About 1927, the York Co. and the Creamery Package Manufacturing Co. brought out direct expansion batch freezers, in which brine was eliminated and ammonia was used directly in contact with the freezing cylinder. In 1925 the Draw-rite ice cream freezing controller, brought out by Farrall and Turnbow, provided a means for much more accurately controlling the freezing process in the batch freezer.

In 1927 experiments by the Vogt Co. with a lard cooler seemed to offer promise in the development of an improved continuous type of ice cream freezer. By 1929 a few of these machines were in use by the industry, and several equipment manufacturers were busy developing a satisfactory continuous ice cream freezer. By 1935, with the introduction of the Creamery Package continuous ice cream freezer and the improved models of the Vogt freezer (Figure 6), the entire industry began changing over to continuous type freezers. More efficient production, lower-cost operation, and improved quality of product were brought about by the introduction of these machines. A resultant development was the introduction of the automatic fruit feeders and mix supply tanks that went along with the freezers. Since 1935 the improvments in ice cream freezing have been of a minor nature, dealing principally with better and more sanitary types of construction and more accurate controls. Improved refrigeration systems also have been developed for these freezers, but the basic principles of the continuous freezers have not been changed.

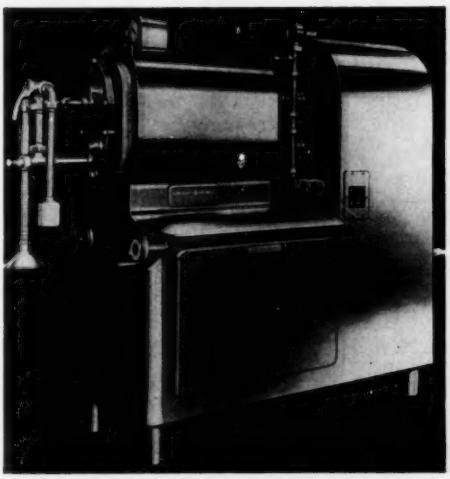

FIG. 6. Practically all commercial ice cream is now made by the continuous method.

An adjunct of the freezer was the development of automatic packaging machines for one, two, or three flavors and the equipment for making fancy center ice cream. These could be attached to the outlet of the continuous freezer.

Milk Drying and Condensing Equipment

Ever since the development of the vacuum pan by Gail Borden, dairymen have been interested in concentrating milk and dairy products. The single-stage vacuum pan was used almost entirely in the dairy industry until about 1940, at which time multiple effect units such as have been used for years in the chemical industry were introduced. The problem of sanitation was solved by improvements in design.

By 1935, the use of stainless steel in making vacuum pans was considered feasible. Fabrication problems and high cost up to that time had been major obstacles. At present, most milk evaporating equipment is constructed throughout of stainless steel, with resultant improvements in flavor of the product.

Powdered milk has been manufactured since 1900, but it was not until about 1923, with the development of the Gray-Jensen spray system of milk powder production (Figure 7), that the nonfat dry milk industry began to grow rapidly. Previous to that time several large companies manufactured powdered milk, but the process was very closely controlled and the total production was relatively small. During the thirties, the installation of powdered milk equipment increased slowly. During World War II the industry grew rapidly when extensive research demonstrated the way to produce a superior quality of nonfat dry milk solids as well as a more satisfactory whole milk powder. Principal among the improvements made during the forties in dry milk equipment was the adoption of stainless steel evaporating equipment for precondensing the product, an entire stainless steel drying chamber, and methods of quickly cooling the powdered product. Developments in packaging the product in vacuum or an inert gas also are of note. Roller dryers of the vacuum or atmospheric type, though long used, have not proved as popular as the spray methods, primarily because of cost and quality differences.

Cheese Equipment

At the turn of the century, the cheese business was an important branch of the dairy

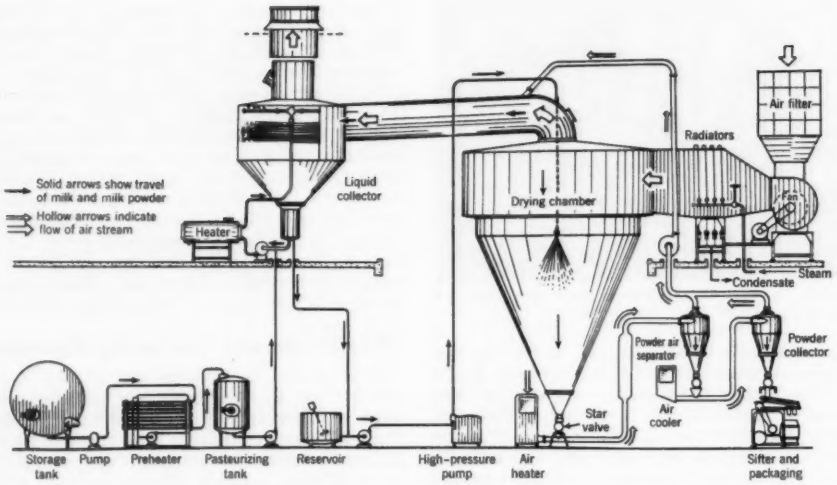

FIG. 7. The spray process is the most common method of drying milk today.

industry. Many small cheese factories were scattered about the country. Their equipment was simple, consisting principally of a small boiler and a few milk cans and cheese vats. The cheese vats were made of tinned steel or copper surrounded by wooden housings. Hand tools were the rule in manipulating the curd and processing the cheese.

Very few changes took place in cheese plant equipment until the middle thirties, at which time many of the plants began to pasteurize their milk, which necessitated adding a pasteurizer. The cheese vat today is of the same general design as 50 years ago but is usually made of stainless steel. Also, there are now mechanical devices for stirring the curd and hydraulic presses for removing whey. Much thought has been given to the development of a continuous process for the manufacture of cheese, and several experimental units have been built.

Important improvements have been made in refrigeration and storage rooms for cheese, in the control of temperature and humidity, and in handling equipment. As in other branches of the dairy machinery business, the equipment for cheese factories has been improved in its sanitary features.

Homogenization

About the turn of the century, a Frenchman by the name of Gaulin invented the homogenizer, which consisted principally of a high-pressure pump and a poppet-type valve, through which a fluid product could be forced at high pressure. This invention was very beneficial to the evaporated milk and ice cream manufacturers, who were the major users of the machines until the advent of wide-spread production of homogenized fluid milk, which began about 1940.

Prior to 1930, the homogenizers were heavy-duty, slow-speed pumps fitted with three or six cylinders. They were belt-driven and made of bronze, usually with a specially hardened steel or agate homogenizer valve of the poppet type. A number of different valves were developed, including the multiple stack disk type, but up until about 1940, most homogenizers were equipped with poppet-type valves. About 1921, two-stage homogenizer valves became popular, particularly in the ice cream industry. It was found that the double homogenizing treatment caused less clumping of the fat particles, particularly in high fat mixes. Since 1940 several companies have brought out single-service type homogenizing valves.

Very few improvements other than the use of the direct motor drive were made until the middle thirties, when several manufacturers brought out machines that could be easily dismantled for cleaning. The milk industry, anxious to market homogenized milk of good keeping quality, was handicapped by the unsanitary features of the machines then generally available. By 1940, however, the major manufacturers were making machines that met the sanitary requirements of the milk industry. With the advent of the sanitary machines and the development of a standard U. S. Public Health Service test for determining when milk was properly homogenized, the milk industry adopted homogenization of market milk on a broad scale. This is one of the most significant developments in the past two decades.

Packaging

Several significant developments have occurred in the packaging phase of the dairy business. Perhaps the most far-reaching effect has been the development of the paper milk bottle, which, although in use as early as 1920, did not become widely used until the middle thirties, when new and improved cartons and carton-producing machinery and fillers were introduced by the American Can Co. and the Excello Corp.

Another significant development was the use of paper containers for bulk ice cream, which accompanied the wide-spread use of the continuous freezer in 1935. Semi-automatic filling machines for bulk ice cream containers and completely automatic filling machines for smaller paper packages were developed during the late thirties. Automatic Dixie cup ice cream fillers were used in many plants as early as 1935. Automatic packaging and wrapping machines for butter, cheese, and similar products were widely adopted in the thirties.

Fillers for Milk and Cream Containers

Previous to 1920, practically all milk bottles were filled in either hand-operated or semi-automatic machines. In the early twenties, the rotary, automatic bottle filler and capper of the gravity type was in almost universal use. During this period also, special sanitary covers for bottle caps were introduced, but they were not widely used for some years.

In 1929, Mojonnier Brothers introduced from England a new and revolutionary type of bottle filler of the vacuum type (Figure 8). Since

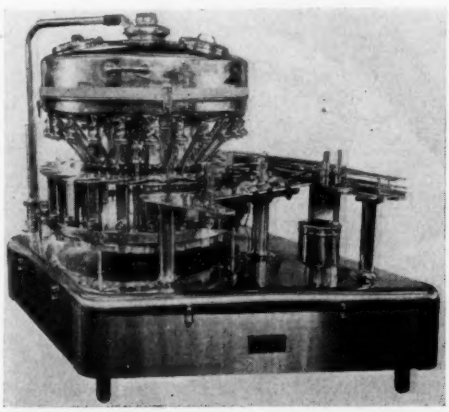

FIG. 8. Modern glass milk bottle filling equipment involves the use of vacuum methods.

that time several other designs of vacuum type bottle fillers have been developed. Of significance also is the American Can Co. bottle filler, which is adapted to the use of preformed paper milk cartons manufactured by that company. The Pure-Pak system, introduced in the middle thirties, was of particular interest in that it formed and assembled the paper milk carton from blanks as used.

Another interesting development is the system which places a sterilized product (milk or cream) in a sterilized container under aseptic conditions, usually in the presence of superheated steam. The container used is usually a tin-lined metal can.

Can Washing Equipment

Previous to 1920, most of the 10-gal. milk cans were washed by hand, but by that date the milk industry had become so large that mechanical continuous can-washing equipment was needed. Machines using jets of washing solution, sterilizing water, and hot air in proper sequence proved to be successful. In small plants the rotary washer was most popular, and the straightaway type was most used in larger plants. During the twenties, much experimenting was done with rising jets, the use of superheated steam for further sterilizing the cans, the use of water treatment systems for preparing the wash solution, and various methods of automatically replacing the lids on cans.

Further improvements since that date have been made mostly in the more efficient utilization of steam, use of hot air for drying the can, automatic control of solution strength, and improvements in types of valves and mechanisms for feeding the cans to and from the washer. As early as 1925, reasonably successful continuous can-washing machines were available which would wash the can and replace the lid automatically.

In conjunction with the can washer and receiving room set-up, it should be mentioned that improvement in weigh-can design has been very marked. In the middle twenties little attention was given to foaming or to methods of obtaining accurate samples from weigh cans. The advent of the 3-A standards, in 1938 to 1940, resulted in improvements in design to insure more accurate measurement and sampling, effective sanitation, and rapid operation. The development of the semi-automatic can-dumping equipment and of printed ticket weighing were in the interest of greater accuracy and economy.

An important development in milk handling has been the elimination of the can washer as a result of the use of bulk handling on farms. This practice is becoming so widespread that many plants have eliminated the milk-receiving room and its attendant operations.

Bottle Washers

Milk bottles were washed principally by hand prior to 1915. Then rotating brushes mounted above a sink came into use. This semi-mechanical washing system was a great labor saver and resulted in cleaner bottles. About 1920, jet-type bottle washers were adopted in the larger plants. The soaker-type washer, which had been used

for a number of years in the brewing plants, was adapted to wash milk bottles in the early twenties and by 1930 was in common use. In those days there was considerable discussion concerning whether the rotating brush was a necessary adjunct to the soaker-type washer or whether the air brush was superior. Some operators claimed that neither was necessary and that a simple jet of water in addition to the soaker treatment was all that was needed.

Improvements in bottle washers in the past 20 years have been principally in minor mechanical developments and the use of machines that will wash 2-quart and gallon containers. The use of paper cartons for milk in many plants has greatly decreased the need for washing equipment.

Sewage Disposal

In the early days it was a common practice for country plants to drain wash water and other plant wastes directly into a nearby stream. The sewage from large plants was usually disposed of in the city waste disposal system. As the density of population increased and the plants became larger, it became necessary to find some other means of disposing of wastes. Many kinds of sewage disposal systems have been tried through the years, but greatest use has been made of the trickling filter. Disposal through spray irrigation systems has been successful in many installations. Furrow irrigation is also being used in some areas.

A number of the larger manufacturing companies, particularly the National Dairy Products Corp., made exhaustive studies of various means of waste disposal and also of methods of decreasing the amount of waste material. Prevention of leaks and the utilization of by-products were studied. It was found that the average dairy plant, through careless operation, was unnecessarily enlarging its sewage disposal problem. It was also shown that in many plants much of the whey and skimmed milk, which went down the drain, could be dried or otherwise utilized to make a worthwhile, salable product and at the same time eliminate a part of the sewage disposal problem.

Delivery Equipment for Bottled Milk

In many parts of the country in 1905 much of the milk was distributed to the consumer in bulk. Usually the driver dipped the milk into the customer's container. It was soon found that from a sanitary standpoint it was much better to bottle the milk in a central bottling plant and deliver it in sealed containers. The usual retail distribution equipment consisted of a horse-drawn wagon and crushed ice for chilling the milk. About 1935, many companies changed over to motor-driven delivery equipment. Today the use of trucks with refrigerated bodies for both retail and wholesale routes is gaining in importance.

Atomic Radiation

Atomic energy probably will affect the milk business in a number of ways. From an engineering standpoint, one of the most interesting developments is the use of radiant energy to measure the density of dairy products as they flow through pipe lines. This provides a means for controlling composition and the uniformity of operation.

Many laboratory experiments in the use of atomic radiation for the sterilizing or pasteurizing of milk have been conducted. At the present time, no satisfactory method of applying energy for this purpose has been found successful, owing to, among other things, a bad effect on the flavor of the milk. However, many promising results have been obtained in the use of radiant atomic energy for treating packaged dairy products.

Future possibilities for the use of atomic energy in the dairy industry involve such matters as the generation of electric power, the sterilization of products, and treatment of wash water and sewage. Figure 9 shows an experimental one million volt electron gun that has been used for treating milk.

3-A Standards

One of the most significant developments in the dairy engineering field is the cooperative

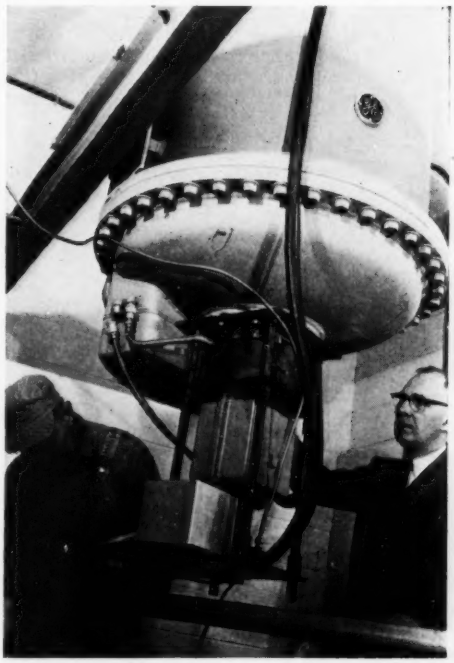

FIG. 9. An experimental million-volt electron beam generator being readied for cold sterilization experiments for dairy products.

program that established the 3-A sanitary standards. These are the result of joint efforts of the International Association of Milk and Food Sanitarians, the U. S. Public Health Service, and the Dairy Industry Committee and represent the thinking of all branches of the dairy industry, including users, regulatory officials, and equipment manufacturers. These standards have been developed to cover most of the major items of dairy equipment, including such machines as milk storage tanks, milk tanks to be mounted on trucks, electric motors, and sanitary fittings.

Perhaps no other single factor has had such influence on improving the sanitary design of dairy equipment as has this particular activity. It has resulted in a quality of construction that has set standards for the entire food industry.

Future Possibilities

Progress in dairy engineering has truly been remarkable in the last 50 years. Not only has sanitary construction been widely adopted, but improvements in efficiency have been marked. The dairy industry has made extensive use of newer knowledge in metallurgy, in machine design, and in automation.

From a look into the future, it appears that automation will be of increasing importance. Undoubtedly, great progress will be made in the development of new processes involving machinery and equipment. It is possible that cold sterilization methods will be developed that will be satisfactory for the treatment of milk and its products. There will be great improvements in packaging of dairy products and in the field of distribution. The result of all this development will be an improved and cheaper product for the consumer, which will make for even greater permanency of the dairy industry.

Fifty Years of Progress in Dairy Plant Sanitation Methods[1]

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The first meeting of the Society of American Bacteriologists in 1899 aroused considerable interest in dairy sanitation. The following papers at that meeting focused attention on the need for dairy plant sanitation programs: "Certain Practical Applications of Bacteriology to Dairying" by Conn, "The Importance of Bacterial Tests in the Sanitary Supervision of Municipal Milk Supplies" by Leighton, "On the Commercial Value of Bacteriological Analysis of Milk Supplies" by Keith, "Is It Practicable for Health Departments to Prevent the Sale of Milk Containing Excessive Numbers of Bacteria?" by Park, and "A Bacteriological Examination of the Boston Milk Supply" by Sedgwick.

O. W. Kaufmann

Early Dairy Operations

Fifty years ago dairy plant sanitation amounted to little more than kitchen cleanliness. Even this was difficult to attain as cleaners were inefficient and processing equipment was not of sanitary construction. Almost every phase of plant activity contributed some contamination. The conical cooler used to cool and aerate the milk was not easy to clean. Holes were "punched at random to speed up the process or plugged to slow it down" depending on the temperature of the well water. No consideration was given to the problem of cleaning. The open surface cooler was not much better. Polluted water or dust from the city streets could filter through the open cellar windows directly into the milk-processing room and contaminate the product during cooling.

Can washing was a laborious task designed mainly to rinse the residual milk from the can. Milkstone or hard water deposits, which inevitably formed, were almost impossible to remove. Usually, the cans were hand brushed in one-compartment sinks. No rinse tank was provided and little, if any, rinsing was undertaken. After being washed, the cans were inverted over a steam jet. The procedure was noisy but it did not kill bacteria, and the majority of the cans smelled putrid.

Milk bottles were washed in the same room used to process the milk. Most dairy sanitarians objected to this practice and recommended that it be carried out in a separate room. For the most part, washing was accomplished by hand brushing. Two-compartment sinks were used. All the bottles were rinsed with warm water in the first compartment and brushed in a solution of washing soda in the second. Bottle sanitation improved when a steam-driven wheel with a revolving brush was developed. About this time an automatic bottle washer was introduced which flushed the residual milk from the bottle, sprayed it with hot alkali to clean it, and rinsed it with water at approximately 212° F. to sanitize it. Exhaust steam from a pump was utilized to heat the final rinse water, as steam was too expensive to produce. The clean bottles were removed from the washer in a rack to minimize contamination due to handling.

Quart bottles were used almost exclusively. The shape varied considerably and this complicated the washing operation. Bottles with long narrow necks designed to exaggerate the amount of cream present were used more frequently than those with short necks and wide mouths. The latter were easier to clean but, since emphasis was placed on the fat content of the milk rather than on the features which insured cleanliness, these bottles were never widely used. Bottles with permanent snap-down covers were used to a very limited extent since they were difficult to clean. Some milk was sold in two-quart bottles but this container was not accepted by the consumer because of an unsanitary thumbscrew closure. The early glass bottles discolored as a result of impurities such as manganese and iron and gave milk a skimmed appearance. To circumvent this difficulty the glass was sometimes tinted yellow to improve the appearance of the bottled product. Tinted bottles were difficult to inspect for milkstone accumulations.

Bottle fillers were not of sanitary construction and could not be disassembled for cleaning. Leather gaskets were used as valve seats, and drip guards were unknown. Corners were square, crevices were common, and surfaces were rough compared to the modern finishes. Capping was essentially a manual operation, and considerable handling of the pouring lip and closure was inevitable. Failure to synchronize the bottle-washing operation with the filling operation necessitated storage of clean bottles. Storage facilities were often filthy and presented an easy route for rodent and insect contamination of the clean container. Dairy plant inspection and sanitation programs aided considerably in correcting this defect.

[1] Journal Article No. 1909, Michigan Agricultural Experiment Station.

The Modern Milk Plant

The dairy plant of 1956 bears little resemblance to its 50-year-old predecessor. The combined efforts of the dairy technologist and dairy engineer have been responsible for many devices which improved plant sanitation. The can conveyor and dump rack simplified the task of unloading and dumping the milk. The job was easier, less milk was spilled, the platform was cleaner, fewer flies found a food supply, and plant sanitation improved. The primary purpose was more efficient operation but a secondary result, improved plant sanitation, cannot be overlooked.

The automatic can-washing machine has for the most part eliminated the damp, foul-smelling can of yesteryear. That there has been progress in can sanitation is evidenced by the fact that a bacterial count of less than 1,000 per can and cover is presently being used by the industry as a standard of efficient sanitization. The bottle washing operation likewise has been redesigned to insure thorough cleaning. Rinse tanks, soaker tanks, balanced alkaline detergents, and chlorine rinses are used to obtain clean and, in many cases, sterile bottles. Manual handling of the clean container has been eliminated by the introduction of conveyors connecting the washer and filler. Improvement in glass technology has resulted in the manufacture of clear glass bottles, which can readily be inspected. Cleanliness is imperative with clear glass bottles, and the dairy plant operator must keep the bottle washer operating properly.

The modern filler is a complicated device compared to its forerunner but it is constructed with sanitation in mind. Hard rubber gaskets are used in place of leather; highly polished stainless steel has replaced tinned iron, and joints and corners are smooth. Notwithstanding the intricate design of this equipment with its numerous springs, plungers, pistons, and gaskets, it can be completely disassembled for cleaning and sanitizing. The automatic capping machine has eliminated the unsanitary practice of "thumb-capping," and every effort is made to prevent contamination by human contact. Sanitary recommendations in the modern dairy include a double seal to eliminate contamination of the pouring lip by the milk delivery man.

The modern plant has one feature that its predecessor lacked entirely. That is the plant laboratory, which supplies bacteriological and chemical services. Its prime function is to maintain quality control of the product through sanitation. The incorporation of the laboratory as a part of the plant enables it to furnish continuous and immediate service to each operation in the plant from the receiving room to the refrigerated storage room.

Standard Methods for the Examination of Dairy Products describes the chemical and bacteriological control procedures to be used in the dairy laboratory. It is published by the American Public Health Association. It is constantly under revision and is in its tenth edition. All raw milk and raw ingredients used by the plant are tested to insure compliance with quality standards. The standard plate count or some variation thereof is used to determine the degree of microbial contamination. Maximum bacterial tolerances have been set for many products, and counts in excess of these indicate poor sanitary practices. In pasteurized dairy products the coliform test is used to indicate post-pasteurization contamination due to improper sanitary procedures. A standard of less than ten per milliliter or gram is required in most states. In actual practice, plant sanitation techniques have been perfected to the extent that coliform counts of less than one per milliliter are common. In the manufacture of butter the efficiency of the sanitation program is evaluated by determining the degree of yeast and mold contamination. Counts greater than twenty per milliliter indicate unsanitary production practices or improper treatment. Psychrophilic bacteria in pasteurized market milk or cream are considered by the dairy plant as an index of sanitation. No legal tolerances are recommended but the widespread occurrence of these bacteria in the plant environment, especially in water supplies, makes them suitable as detector organisms indicative of post-pasteurization contamination resulting from unsanitary practices.

The processing equipment is tested to determine the level of contamination after sanitization. Rinse tests or swab tests are used for this purpose. These tests are made routinely by the plant laboratory on sampling vents, cheese vats, storage tanks, bottles, and cans to determine the degree of bacterial contamination. Container counts in excess of one per 1 ml. of volume or surface counts greater than 500 per 40 sq. in. of area indicate improper cleaning and unsatisfactory sanitization.

The chemical tests performed by the plant laboratory also assure proper sanitation practices. The strength of the washing solution in the can washer and bottle washer is determined as often as necessary to insure that the proper concentration of cleaning solution is used. The chlorine strength of the rinse water used to sanitize the bottles is tested routinely. The efficiency of the cleaning technique used in a cleaned-in-place pipeline is evaluated in the plant laboratory by using the chlorine concentration as an indicator. A sharp decrease in chlorine concentration during sanitization indicates the presence of organic matter and unclean lines.

Organizing a routine test program throughout the plant assists in attaining the desired degree of sanitation and at the same time provides a check for each operation. Many smaller dairy plants that do not have a laboratory are provided a quality control service by the board of health laboratories. These official agencies routinely test the raw and finished products and keep the plants informed as to the progress they

are making. With this information even the small plant can evaluate and improve its sanitation program.

3A Standards Committee

Sanitary progress in plant operations in the last 50 years has been due in part to the standardization of dairy equipment. This was achieved through the formation of an organization known as the 3A Standards Committee. It is composed of representatives of the International Association of Milk and Food Sanitarians, the United States Public Health Service, and the Dairy Industry Committee. This group sets up the standards for the material used in fabricating dairy equipment and passes on features of sanitary construction. The former prevents the use of material such as aluminum or iron, which would react with the modern detergents and deteriorate on cleaning. The latter makes techniques such as in-place cleaning and spray cleaning possible.

Detergents and Sanitizers

Dairy plant sanitation advanced considerably with the discovery of new detergents. In 1906 pure lye and lye soap were the main alkaline cleaners. Weak lye solutions were used for hand cleaning operations and strong solutions were used in mechanical washers. Alkaline solutions of this type were of limited value in removing milkstone but they were excellent for removing fatty deposits. Their strong alkalinity made them dangerous to handle and corrosive to certain metals. This prevented extensive use, and the proper degree of cleanliness was difficult to obtain. Lye soap was used extensively as a general cleaner. It was mild and less corrosive than lye. In certain water supplies these soaps formed hard water precipitates, which combined with milk to form a gummy substance. This residue adhered tenaciously to milk cans, bottles, or equipment and made cleaning very difficult. Rinsing with untreated water or steam to remove this film was unsuccessful and build-up occurred.

Soda ash, sodium metasilicate, and sodium bicarbonate were incorporated with lye to improve it. Soda ash softened the water to a limited extent. Sodium metasilicate contributed to the alkalinity and inhibited the corrosion of white metal, which was extensively used before stainless steel became available. Sodium bicarbonate was used as filler and buffer. These compounds improved the cleaners to some extent, but they lacked wetting ability and were inefficient water softeners.

Advances in the chemistry of soil removal led to the addition of phosphates to cleaner formulations to improve the cleansing action. Trisodium phosphate was one of the first compounds used. It was a poor detergent since it softened water by precipitating the insoluble compounds as a gummy residue. The addition of polyphosphates to cleaners was another step forward. These compounds aided emulsification and soil dispersion and softened water by sequestering the mineral elements rather than by precipitation. This eliminated the gummy film. These agents are noncorrosive and nonirritating.

The development of wetting agents and their incorporation in cleaning compounds further improved sanitation chemicals. Scales and Kemp in 1940 reported, "The application of wetter water to dairy and milk plant use must be in the nature of a prophecy for, at present, so little is used that it is negligible." Today anionic and nonionic wetting agents are readily available and commonly used in detergent formulations. Anionic agents are most frequently employed. Numerous chemical combinations are possible, and "tailor-made" wetting agents of specific anionic configuration are manufactured for specific problems. These agents have been found to react synergistically with sodium sulfate. In this combination their activity is increased about 33% over the pure substance. Nonionics are new. They are compatible with anionic and cationic solutions and appear promising for this reason but little is known about them at present.

The prevention of hard water precipitates was one of the biggest problems in any cleaning operation. Inorganic sequestration by polyphosphates was partially effective in combating this difficulty, but recently organic chelating agents have been developed which are considerably more effective. In addition, these compounds are heat-stable and are used in detergent formulations for in-place cleaning and spray cleaning techniques where high temperatures are necessary. Organic chelates vary in their ability to sequester calcium, magnesium, or iron, and specific chelates are required for specific problems. Alkaline detergents today are complex compounds. They contain basic alkalis, polyphosphate wetting agents, and chelating agents. All the constituents must be of the proper type and in the proper concentration to remove effectively the type of soil present in dairy equipment. They are called balanced alkaline cleaners and are often tailor-made to meet the requirements of the water supply.

Highly ionizable muriatic acid was the first mineral acid used as a cleaner. It removed milkstone and precipitates due to hard water but its use was limited because of its corrosiveness. Noncorrosive, nonirritating, stable organic acid cleaners, such as hydroxyacetic acid and gluconic acid, have replaced muriatic acid as a detergent. Calcium and magnesium precipitates due to water or milk are removed by these mild organic acids and more efficient cleaning is possible with greater safety to the personnel. Corrosion inhibitors are added to these acid cleaners to prevent metallic degradation of the highly polished surface.

Detergent sanitizers which clean and sanitize simultaneously are a recent development in the field of sanitation. This procedure is contrary to the age-old concept that cleanliness must precede bactericidal treatment. It is indicative of the new approach that is being considered by those interested in detergents and soil removal. Chlorine-bearing compounds or cationic bactericidal agents are combined with a suitable alkaline detergent in these formulations. In addition to sanitization of the equipment, the bacterial contamination of the wash water is controlled. Chlorinated alkaline cleaners also possess enhanced cleaning activity, which at present can not be explained. Iodine or bromine also may prove suitable for use in these formulations, but developments along these lines are limited at present. Most state regulations require sanitization immediately preceding use. This eliminates the possibility of a one-step cleaning and sanitizing operation, but the increased efficiency of the detergent sanitizer is sufficient to insure its future as a new cleaning compound. Detergent sanitizers find special application in cleaning ice cream freezers, ice cream molds, and butter churns where accessibility is limited.

Sanitization of clean equipment has always been practiced in the dairy plant. In 1906 live steam or hot water was frequently used as a bactericide but the method was costly. Sanitization with these agents was difficult to accomplish since most plants lacked suitable equipment. Bleaching powder was commonly used for bottle sanitization. Its use on metal equipment was limited because it was too corrosive.

Chlorine remains one of the best sanitizers for dairy equipment. When properly used, it does not corrode the stainless steel used in the modern plant. If misused, corrosion may occur. Chlorine in combination with certain organic compounds produces a slow-acting sanitizer with prolonged activity. Many of these chloramine sanitizers are stable at high temperatures. They are used where mild but continuous disinfectant action is desired.

Quaternary ammonium compounds are relatively new sanitizers in the dairy plant. They are noncorrosive, more stable than hypochlorites in the presence of organic matter, and surface active. They are used to sanitize painted areas, milk cases, and walls where chlorine might be too corrosive or be inactivated. Iodine in combination with certain nonionic wetting agents is noncorrosive, nonstaining and nonirritating. These iodophors possess enhanced germicidal activity over pure iodine. Fungicidal paint is used to control mold growth on the walls and ceilings of butter storage rooms, cheese curing rooms, and walk-in coolers. Solubilized copper-8-quinolinolate is incorporated in the paint to provide this activity. These paints are particularly effective in the cook room of process cheese plants where high temperatures and high humidities prevail throughout the season. Improved sanitizers and sanitization techniques have greatly reduced product contamination at all stages of processing and are largely responsible for the low levels of microbial contamination observed in the finished product produced in the modern plant.

Modern Scientific Cleaning Techniques

Cleaning in the modern plant is a major operation which follows a definite routine. A satisfactory cleaning routine utilizes both alkaline and acid detergents. In general, alkaline cleaners are used daily; an acid cleaner is employed only every third or fourth day to minimize the possibility of corrosion. Alternating a balanced alkaline cleaner with an acid cleaner prevents proteinaceous films and milkstone deposits from building up. This is known as the alternate cleaning technique. It is a simple sequence but its formal organization into the clean-up operation is vital to the success of the sanitation program.

Another technique to simplify and increase the efficiency of the cleaning operation utilizes a combination of acid and alkaline detergent. In this technique the equipment is first washed with acid cleaner; alkali is then added to make the solution basic and the equipment is cleaned with this alkaline solution. The reaction between the organic acid cleaner and the alkaline detergent forms certain organic salts which have excellent sequestering ability. Considerable saving in cost is obtained, as the wetting agents of the acid cleaner are re-used. This combination acid-alkali cleaning technique saves time and detergent, conserves water and steam, and improves the sanitary condition of the equipment. Single and double effect evaporators, tubular heat exchangers, and high-temperature, short-time plate pasteurizers are particularly adapted to cleaning by this new process. The latter are cleaned in place on an experimental basis at present under the supervision of local regulatory agencies. Cleaning by forward and reverse flow or by splitting the unit into two sections may make in-place cleaning of this unit possible.

In-place cleaning of hot or cold pipelines is a relatively new innovation in cleaning. It is a radical departure from the conventional takedown method of washing and has laid the foundation for other semi-automatic techniques. Equipment designed according to 3A specifications is essential in all semi-automatic cleaning procedures. These CIP pipelines, as they are called, are cleaned immediately after use by flushing with warm water, recirculating a special balanced alkaline detergent at 120° to 160° F. for 10 to 20 minutes, and rinsing with clean warm water. Hard water is treated to prevent the formation of water spots which may serve as foci for milkstone build-up. Every third or fourth day, acid cleaner is used in place of the alkali to prevent the accumulation

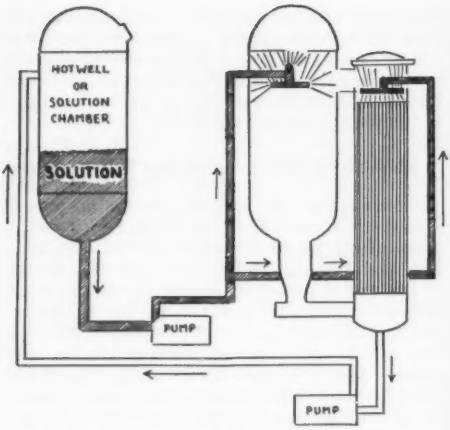

FIG. 1. A schematic diagram illustrating the spray cleaning technique in an evaporator.

of milkstone. Combination acid-alkali cleaning is also used in these systems.

Spray cleaning is another new technique. Vacuum pans, evaporators, storage tanks, hot wells and other enclosed equipment can be cleaned by this process (Figure 1). In spray cleaning, strong alkali and acid cleaning solutions at elevated temperatures are continuously flushed over the equipment by using specially designed nozzles. Complete coverage is obtained by fixed spray balls or rotary jets which forcibly eject the hot cleaning solution to provide the necessary scrubbing action. A portable rotary jet unit is shown in Figures 2 and 3. The detergent solutions are heated directly by steam injection. With vacuum pans this is a departure from the old cleaning technique that utilized the heating chamber to heat the cleaner. Keeping the processing equipment cold reduces the burn-on and simplifies the operation. This technique saves labor and steam. Only one-fourth the amount of water is required as compared to the manual cleaning method. Mounting a sanitary spray cleaning unit permanently in a tank or storage tank is being studied at present. This permanent unit may replace the portable unit in the future. Hand-operated spray guns are used to aid in cleaning bottle-fillers, cappers, sealers, cheese presses, and other complicated devices. Dismantling and hand scrubbing are still necessary for thorough cleaning.

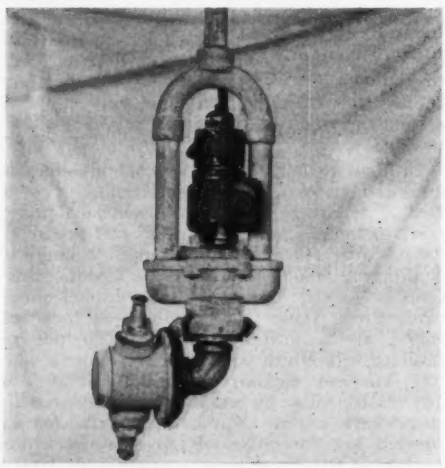

FIG. 2. Rotary jet spray for cleaning bulk tankers or storage tanks.

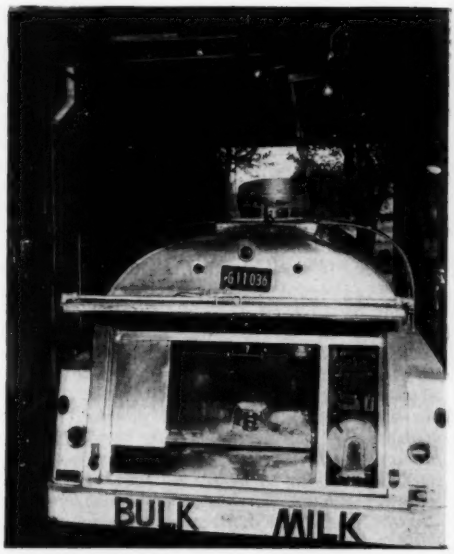

FIG. 3. Portable rotary jet spray for spray cleaning a tank truck. Note automatic control panel.

Special Sanitation Problems

The American Dairy Science Association in 1939 recognized the sanitation problems facing the industry and appointed a Committee on Sanitation Procedures. Burgwald, Tracy, and Kelly were selected to serve on this committee and make recommendations. Sanitary practices in ice cream and frozen dessert manufacturing were subjected to considerable study. Brown, Prucha, and Tracy devised practical procedures for improving the sanitary quality of flavoring extracts and coloring materials added to ice cream mix prior to freezing. Nut meats and fresh fruits were also found to be highly contaminated with bacteria. Procedures to reduce this contamination and improve the santary quality of the finished product were recommended. These procedures improved the sanitary quality of the finished product. A bacterio-

logical standard of 100,000 per gram of ice cream or frozen dessert is generally required by most states. Sanitation in the ice cream industry has progressed to the extent that well operated plants use 25,000 to 50,000 per gram as a plant standard.

Improved sanitary procedures are in part responsible for the increased shelf life of dairy products. Ropy milk or fruity milk spoilage has replaced the typical sour milk spoilage of 1906. The former are both caused by psychrophilic bacteria which are commonly found in dairy water supplies. Since these organisms are killed by pasteurization and proper sanitization, their presence in large numbers in freshly pasteurized milk is indicative of poor sanitary practices.

Psychrophilic bacteria are also important contaminants in cottage cheese. They are responsible for many off-flavors. Sanitary control in the cottage cheese plant has made it necessary to improve the city water supply. Potable water cannot be considered satisfactory for use in the modern cheese plant since the bacteriological standards for water used in the cheese plant are far more severe than those required for safe drinking water. Nonpathogenic psychrophiles may be consumed in drinking water without any injurious effect, but these organisms cannot be tolerated in the water used to wash cottage cheese or butter. In-line, breakpoint chlorination of the plant water supply is practiced in many plants to control the psychrophilic spoilage.

There is no single phase of activity in the dairy plant of 1956 that is not considered in the light of sanitation. Disease outbreaks attributed to milk are almost unknown as a result of the high sanitation standards in the dairy industry today. Table 1 summarizes the disease outbreaks due to dairy products from 1906 to 1954. Outbreaks due to other food products, exclusive of water, are shown for comparison. The 383 milk-borne disease outbreaks listed from 1906 to 1916 undoubtedly represent the minimum number, as poor diagnosis and failure to report disease outbreaks were common in this period. It is important to note that disease outbreaks due to dairy foods decreased greatly from 1906 to 1954, although the consumption of dairy products increased from 64 billion to 115 billion pounds. The outbreak ratio in 1906 was 1 per 170,000,000 lb. of milk as compared with 1 per 1,400,000,000 lb. in 1954.

TABLE 1

Milk and food borne disease outbreaks from 1906 to 1954

Period	Milk outbreaks	Food outbreaks
1906-1916	383	——
1917-1926	272	——[a]
1927-1936	417	111
1937-1946	391	2,040
1947-1954	83	1,993

[a] Botulinum poisoning only.

It is little wonder that other food industries are basing their sanitation programs on the techniques developed by the dairy industry in the last 50 years.

Activities in Dairy Manufacturing Extension

EVERT WALLENFELDT

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The main object of dairy manufacturing extension is to apply the findings of research and practical experience to the production and processing of high quality dairy products in order to bring about the best possible consumer acceptance. Dairy manufacturing extension also embraces the activities related to the improvement of efficiency in processing these products. These activities are concerned with producers, processors, and consumers.

Work with Producers

The founders of the American Dairy Science Association were concerned with the improvement of dairy products and the development of the sanitation consciousness necessary to bring it about. At the first annual conference of the Official Dairy Instructors' Association, R. A. Pearson, president of the Association, urged that more attention be given to extension work in dairy sanitation. He called attention to the general lack of producer understanding of the importance of sanitation in milk production and recommended the appointment of a committee to study this problem. Such a committee, consisting of B. W. Rawl, J. M. Trumand, and E. S. Guthrie, made its recommendations at the third annual conference in 1908. The following results of a survey conducted by this committee give an indication of the extent of dairy quality improvement work a half-century ago.

E. Wallenfeldt

New Hampshire reported that one man was employed "to encourage testing of dairy herds, to conduct dairy surveys and to encourage butter scoring contests."

New York showed that 12 men were employed by the State College of Agriculture and that 10 butter and cheese instructors were employed by the State Department of Agriculture. This report states that the work included "all lines of dairying" and that "the usual" methods of dairy school and fieldwork were practiced. It is of particular interest that 12 departments were cooperating in this work. This seems to be one of the early examples of inter-departmental cooperation on dairy quality improvement.

In Ohio one man was employed by the state university to cover the entire state in work with both consumers and producers. In Wisconsin three men were employed by the College of Agriculture and 11 men were employed by the Dairy and Food Commission for this work. These 11 men were engaged in educational extension work as well as enforcement.

It is interesting to note that this first quality committee of the Association concluded that failure to produce high quality milk products was due not to lack of knowledge but to the fact that a greater part of the knowledge was not being used by dairymen.

Another survey conducted by C. J. Babcock of the U. S. Department of Agriculture 30 years later, showed that 15.2% of dairy extension work in the United States was related to quality improvement. Only half of this activity was concerned with quality improvement of milk and cream on the farm; the other half pertained to improvement of manufacturing methods. The 46 states that reported had an

FIG. 1. An important phase of extension activities is work with the milk producers.

FIG. 2. The story of the causes of poor quality milk should be told simply.

average of 1.7 workers in dairy production extension. This compares with less than 0.15 men doing extension work on sanitary milk production methods. A 1955 list shows no substantial increase in the number of Land-Grant college extension workers on quality improvement since Babcock's survey of 1938.

Work with Processors

Individual problem extension or "trouble shooting" was done by workers in the Land-Grant colleges long before the organization of the Official Dairy Instructors' Association. For example, H. P. Armsby of Wisconsin in 1884 reported that he was frequently called on to determine whether or not milk was adulterated. During 1885, he reported the analyses of 621 samples of milk, 215 of cream, 134 of butter, and 6 of buttermilk. Individual problem or "trouble shooting" work has continued since that time. Much of this has been done by resident staff members of the agricultural colleges.

Organized Work with Dairy Plants

Organized extension work with dairy plants was common as early as a decade before the founding of the Official Dairy Instructors' Association. During 1896-1897, E. H. Farrington of Wisconsin worked with 52 creameries on improvement of butter quality and creamery efficiency. During that same time J. W. Decker visited 104 Wisconsin cheese factories and worked with them on the improvement of quality and yields of cheese.

A number of colleges were conducting butter- and cheese-scoring exhibitions at the time of the founding of the A.D.S.A. This work grew rapidly, and by 1908 Wisconsin reported active participation by 618 creameries and 458 cheese factories. Starter culture improvement was another early extension activity. Usually, the agricultural bacteriology departments worked with the dairy departments on this project. In Wisconsin cultures were supplied to 150 cooperating cheese factories during 1908. Follow-up work in the field was undertaken. H. L. Russell of the University of Wisconsin reported that by 1916 plans were to have a field instructor visit all plants having trouble with low-score butter and cheese.

A WATER SYSTEM
IS YOUR MOST IMPORTANT FARM EQUIPMENT
IT WILL SAVE YOU MORE TIME AND LABOR
AND PROVIDE YOU WITH MORE COMFORTS
AND CONVENIENCES THAN ANY OTHER
SINGLE PIECE OF EQUIPMENT
YOU NEED
LOTS OF HOT SOFT WATER
TO PRODUCE QUALITY MILK

FIG. 3. Milk producers need to be taught the importance of a good water system.

Extension work on the improvement of cheese quality by pasteurization of the milk used was given early attention. J. L. Sammis and A. T. Bruhn introduced a method of making Cheddar cheese from pasteurized milk in several Wisconsin factories, during 1914. This development, however, did not spread to a high percentage of the cheese factories in the state until about 25 years later.

Plant Engineering and Management

Dairy plant engineering and management has been a specific project under dairy manufacturing extension for a number of years. An example of this type of work is the over-all appraisal of operating practices to reduce processing costs. This includes efficient use of machinery and facilities, improved records and accounting, work simplification, and consolidation of certain operations.

Illustrations of accomplishments in dairy engineering extension are: *(a)* increase of output by more efficient use of equipment, *(b)* rearrangement of existing plants for greater output per unit of floor space, *(c)* sizing equipment on basis of most economical output, *(d)* introduction of proper construction practices to reduce overhead costs, *(e)* improvement of steam consumption per unit of output, and *(f)* improvement of waste disposal practices.

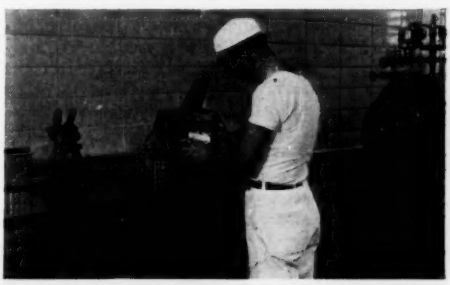

FIG. 4. The laboratory is the heart of a quality control program.

Extensive work also has been done on composition control and efficiency of plant operations. Both manufacturing specialists and marketing specialists have worked on this problem in a number of states. Improvement of laboratory facilities and laboratory methods along with procurement of better trained technical personnel have resulted from this work.

Extension Activities with Consumers, Public Health and Other Regulatory Agencies

Milk ordinances. Dairy manufacturing specialists have long been cognizant of the need for practical city milk ordinances and judicial applications of ordinance provisions. This work has included: *(a)* educational work on the need for practical and uniform milk ordinances, *(b)* information on what constitutes good milk ordinances, *(c)* assisting city councils in drawing up such ordinances and selling them to the public, *(d)* conducting educational work with processors and producers to help them interpret and live up to the detailed requirements in the ordinances, *(e)* helping health departments to provide suitable laboratory facilities and laboratory routine with qualified personnel and to provide adequate inspection with qualified personnel, and *(f)* working with health officers and sanitarians on reciprocal inspection and on uniformity of interpretation and application of the ordinance requirements.

Extensionists have helped to pave the way for this work by presenting essential information to such groups as producers' associations, city councils, parent-and-teachers' associations, women's clubs, service clubs, restaurant associations, and other business and civic groups.

A great deal of the work on the development of satisfactory milk ordinances has been on an individual basis with health departments and city councils, one city at a time. Follow-up work to help in bringing about uniform but effective application of the ordinance requirements has been an important activity after the adoption of each city ordinance. This has been done in cooperation with state boards of health and state departments of agriculture as well as with city health departments.

There has been a special problem where the communities are too small to provide laboratory facilities and qualified sanitarians. Extension workers have cooperated with the state boards of health on a program to organize groups of such smaller towns to do this work collectively.

Promoting consumption of dairy products. The promotion of wider uses of dairy products has generally been done with the cooperation of extension nutritionists and marketing specialists. These activities have ranged from routine extension meetings, exhibits, and classroom instruction materials to extensively organized campaigns involving the press and local leaders throughout the state. Large traveling dairy foods expositions have been staged to portray dramatically the importance of milk and other dairy products in the diet. Home economists and dairy marketing specialists have carried on extensive work in the promotion of a wider use of dairy products, but this paper deals primarily with the activities of dairy manufacturing extension specialists.

Methods in Dairy Manufacturing Extension

Work through county extension agents. The county agricultural extension agent is considered as the official representative of the Land-Grant college in the cooperative agricultural extension system. Therefore, the general policy is to conduct all agricultural extension in the counties through the local county agent. Where the urgency of certain problems is such that there is not time for planning through the county agent, he is generally informed of the work as soon as possible.

The work described by J. D. Brew in New York is a good illustration of organized quality improvement work carried on through the county extension system. This type of work was started shortly after the Smith-Lever Extension Act was passed by Congress. In this plan, the county extension agents schedule dairy manufacturing specialists to grade milk at the receiving rooms of the plants. Usually, the direct microscopic method or other quality tests are used to supplement the regular receiving-room checking. After this, patron meetings scheduled by the county agent are held to discuss the findings and recommendations for improvement. Some of the states that have carried on this type of, or similar, extension work for many years are Iowa, Michi-

FIG. 5. The technologist is constantly looking for means of establishing greater efficiency in the production, processing, and distribution of milk and its products.

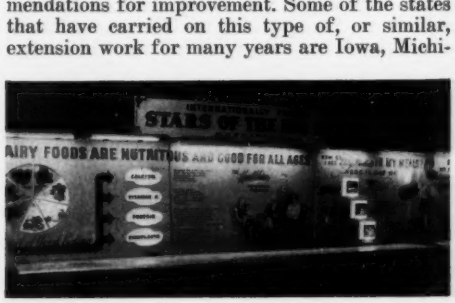

FIG. 6. The home economist can play an important role in educating consumers on the food value of dairy products.

gan, New York, Ohio, Pennsylvania, and Wisconsin.

Scheduling quality improvement topics on the programs of general extension meetings such as farmers' institutes and annual meetings of cooperatives is another common way of giving producers information on quality problems.

Dairy products grading clinics for plant personnel. A number of states have conducted dairy products grading clinics for many years. For convenience, Wisconsin will be used as an illustration. In this state grading clinics were started in 1916, but the program did not reach large numbers of plant people until 1954. At that time, the compulsory grading program for butter went into effect. This stimulated interest in dairy products grading, and the 1956 plans call for about 54 such grading clinics during the year. Not only are products from the plants in the area graded at the clinics but methods for correcting the defects are also discussed. Specialists follow up with visits to the plants to assist the operators in locating and correcting the causes of product defects. All butter graders and buttermakers in each area are included in these clinics. This is a joint project of the State Department of Agriculture and the Extension Service.

The area plan for quality improvement. The organized area plan was in operation during 1916. H. L. Russell of Wisconsin reported that cooperation was obtained in producing higher quality cream in three counties. This was done by means of meetings, personal visitation, and special suggestions distributed to each dairy plant patron in these counties. By 1916, plans were to have a field instructor visit all plants having low-score butter, to assist them in improving quality.

C. J. Babcock has called attention to the importance of getting all of the plant operators in an area to work on quality simultaneously. He has urged the dairy extension specialists to take the initiative and to furnish the leadership in the organization of such area projects. This involves the concerted efforts of the regulatory agencies, the plant operators, the county extension agents, and other local leaders in the area as well as the dairy specialists.

Activities with 4-H Clubs, F.F.A., and other junior groups. Extensive youth programs on milk quality improvement have been developed. Some of the most common of these activities are dairy products judging contests, dairy demonstration contests, dairy quality exhibit contests, and quality milk production projects on the home farms.

The extent of some of these programs is illustrated by the following example. In Wisconsin during one year there were 650 4-H Club participants who gave their demonstrations before audiences totaling more than 84,500 people. These included demonstrations in a majority of the counties. During the same year, a dairy products judging program was conducted in practically every county of the state.

The development of "dairy sanitation consciousness" among the adult 4-H Club and F.F.A. leaders and parents of members has been one of the most important by-products of these youth programs. The teaching of milk

FIG. 7. Youth programs serve as an important method of teaching dairy sanitation.

quality improvement practices in both the high schools and the grades has been promoted by the preparation of courses of study and teaching plans. These include simple teaching aids for the teachers and conducted field trips to dairy plants and outstanding dairy farms.

Interdepartmental and Inter-Agency Cooperation on Dairy Quality Improvement Programs

General development of cooperation. The need for concerted effort on quality improvement has been apparent to quality workers for many years. R. A. Pearson called attention to this at the second annual meeting of the Official Dairy Instructors' Association in 1907. C. J. Babcock has repeatedly called this need to the attention of the Extension Section of the American Dairy Science Association.

P. R. Ellsworth and F. J. Greiner have described extensive coordinated programs in Ohio that involve close cooperation of three major groups. They are the dairy products industry associations, the State Departments of Agriculture, and the Agricultural Extension Service. A number of other states have similar programs, but for convenience the program of one state will be used to illustrate the details of such coordinated programs.

The Agricultural Extension Service of Wisconsin has worked on such an integrated quality improvement program for many years. The program has involved most of the departments within the College of Agriculture, the State Department of Agriculture, the State Board of Health, the State Board for Vocational and Adult Education, the dairy products manufacturers' associations, producers' associations and others.

The purpose of such a program was, first, to develop the kind of public opinion that would support effective quality programs and, secondly, to provide the information needed by producers, processors, educational agencies, regulatory agencies, and others involved. This required the wholehearted cooperation and understanding of the key individuals in all the agencies concerned, such as: *(a)* district extension leaders, *(b)* agricultural and home economics extension specialists, *(c)* county extension agents (agricultural, home demonstration, and club agents), *(d)* other educational agencies, such as the State Board for Vocational and Adult Education and the State Department of Public Instruction, *(e)* regulatory agencies such as the State Department of Agriculture, the State Board of Health, city health departments and others, *(f)* practicing veterinarians and other local professional leaders, *(g)* trade associations, and *(h)* local business people who came in contact with dairymen.

The responsibilities of dairy manufacturing specialists have been: to furnish both technical and practical information to the participating individuals and groups, to help guide the development of sound dairy quality programs by the producers' associations and the dairy processors, and to carry out public educational programs to convince people of the value of quality improvement.

Development of interest in unified quality improvement. The first step in developing a unified program was to get the cooperation of the dairy plant operators, producers, and local leaders such as teachers, professional men, and local business people. The county agents and the agricultural committees in each county were asked to select and appoint farm leaders from each country school district. All of these persons were then asked to come to county-wide meetings to discuss the need for quality improvement. They were asked to vote on the question of whether or not they wanted to launch an educational program on quality improvement in their counties. If the vote was favorable, they were asked to help to plan the programs for their counties. Plans were then worked out for each school district.

After this step, county-wide meetings were held for all of the dairy plant operators. The action taken by the producer leaders was discussed and the plant operators were asked to vote on the question of whether or not such a program should be undertaken. The responsibilities of the plant operators were discussed and agreed upon.

Three years were required to carry out this program in every county of the state. After the completion of this part of the program with producers, follow-up programs with the plants were inaugurated. These included receiving-room inspection of all milk received, quality testing of the milk from each patron at least twice each month, and quality records and field-work. Methods of providing some type of field-work for every plant patron were worked out. Where the plants were too small to employ a fieldman, quality improvement associations were organized, which made it possible for groups of small plants to employ fieldmen jointly.

Setting the stage for a minimum standards milk sanitation code. The State Legislature provided authorization for detailed regulations in the early stages of the program. This was in the form of an enabling act which reads as follows:

> "97.37 Insanitary or adulterated milk and cream; sale; delivery prohibited. It is unlawful to sell or offer for sale, furnish or deliver, or have in possession or under control with intent to sell or offer for sale, or furnish, or deliver as food for man, or to any creamery, cheese factory, milk condensing factory, or milk or cream dealer any adulterated milk or adulterated cream, or any insanitary milk or insanitary cream as defined in section 97.36. The department shall establish standards and prescribe regulations whereby the intake of each producer of milk shall be inspected, sampled and tested by the sediment, methylene blue, or other tests, and insanitary milk or cream shall be rejected as food for man or to be processed or manufactured for food for man, and shall be identified, in a manner that will not prevent its use as food for animals, and regulations for the keeping of the test records, the prevention of further delivery of insanitary milk or cream by such producer, and the correction of the insanitary condition. (1935 c. 550 s. 235; 1939 c. 492)"

More work was necessary to get the support of a greater majority of the producers before all segments of the industry were ready for the development of high minimum legal standards with provisions for effective enforcement. Recognizing this need, the University of Wisconsin Interdepartmental Committee On Milk Quality and the State Department of Agriculture with the cooperation of the State Board of Health and members of the dairy industry planned and staged a large traveling dairy quality exposition. Extensive exhibits, demonstrations, and discussions by about 20 specialists were featured. More than 85,000 people attended these expositions. By developing interest and favorable public opinion, this dramatic program helped to pave the way for the

FIG. 8. Three years were required to carry out a state-wide program of unified quality improvement.

development of a minimum standards milk sanitation code. A manual for follow-up work was prepared by the Interdepartmental Committee on Milk Quality. This outlined the part that each department and agency should play in this over-all dairy quality improvement follow-up program.

Development of a state-wide minimum standards sanitation code. A large industry quality committee was appointed to develop the details of the code. All segments of the industry were represented, including producers and processors from the six major branches of the industry, together with representatives from public agencies such as the Department of Agriculture and the University.

After many months of study and debate, this Committee formulated the state-wide milk sanitation code. The Wisconsin Dairy Federation, representing all dairy interests in the state recommended the legal adoption of this code in accordance with the legislative enabling act. Public hearings were held in nine centers of the state, but legal adoption was delayed because some opposition indicated the need for more educational work before success could be assured. An entire year was required to do this. It was done county by county to give all plant operators and all local producer leaders an opportunity to express their opinions and give suggestions for improvement. Through this method, all could feel that they had a part in its development. The code was then drawn up in the form of regulations which the State Department of Agriculture issued in the form of a legal order on August 15, 1949.

Before the completed code could be effectively applied, all groups concerned had to become fully informed. Specialists from the College and the State Department of Agriculture met with the plant personnel, milk haulers, and inspectors in all of the counties. They also conducted enough producer meetings to serve as "pattern meetings" for the local follow-up work later conducted by the individual county agents.

The local follow-up meetings were of three types: for farmers, for homemakers, and for 4-H Clubs and other youth groups. The fact that 1,719 meetings with a total attendance of 102,588 farm people were held within a 4-month period indicates the scope of this program.

After the development of the "minimum standards" program, similar methods were used for other major programs related to milk quality improvement, such as the state-wide brucellosis eradication program, the state-wide milk house building program, and the state-wide farm water supply improvement program.

Success in these dairy manufacturing extension activities has been very dependent on the cooperation of the many groups concerned. Ways of getting organized cooperation on a state-wide scale have been well demonstrated in a number of state programs. No other agricultural extension project seems to have afforded greater opportunities for cooperation on integrated programs. This cooperation has included not only the subject matter departments within the agricultural colleges but also many other agencies.

Experience which dairy manufacturers have gained in a half-century of work on dairy products improvement shows that effective industry programs are essential for continuous production of high quality dairy products. Extension workers have contributed much to the success of these programs.

Teaching of Dairy Manufacturing

W. S. Arbuckle

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It is appropriate that the American Dairy Science Association, in its semicentennial year, give consideration to teaching, since the organization was originally known as the Official Dairy Instructors Association.

A report in the first issue of the Association Journal in 1917 gives a vivid description of the attitudes and obstacles overcome in establishing the worth of education along agricultural and industrial lines for 50 years previous to the organization of the Official Dairy Instructors Association. Establishing the dignity and prestige of dairy courses in university education was not easy, for it took many years, extending even into recent time. Typical of the problems encountered was the attack, cited in the first issue of the Journal, made by a Greek scholar upon "the buttermakers across the campus for holding their subject on a par with Greek as a part of university education." The field of dairying was not recognized as a separate phase of instruction in our agricultural colleges until just prior to 1900, when a few dairy departments were established. In the next few years, rapid progress was made in teaching methods so that by the time the first issue of the Journal was published, those who taught dairying were looked upon with as much respect as those who taught arithmetic, physics, or grammar.

W. S. Arbuckle

The Apprenticeship Era (1900-1920)

Much of the early dairy teaching was in the nature of the apprenticeship system. Students were taught much as if they were learning a trade. In fact, many of the early instructors were men without degrees but who had acquired a certain amount of proficiency and reputation as excellent buttermakers, cheese makers, or ice cream makers or who had been top-notch dairy products judges.

Ten years after the organization of A.D.S.A., many of the problems facing those teaching dairy manufacturing were recognized. There developed a need for well trained men for teaching and research and for work in industry. The importance of fundamental science was recognized, including the need for physics, chemistry, bacteriology, and nutrition. The normal outlet for the farmers' milk at the turn of the century was for butter and cheese, but later conditions changed with the production of newer products such as ice cream, fancy cheeses, condensed and powdered milk. These changes in commercial conditions necessitated changes in instruction to meet the needs for men trained for responsible positions in these new lines of endeavor. Often this involved changing the emphasis from the dairy cow to the handling of her products. Educators asked themselves, are we giving thorough courses in dairy products and are we furnishing the kind and the quality of instruction which is needed? This question, incidentally, is as pertinent today as it was 50 years ago. In the early period, the prominent men in dairy work had B.S., or at the most M.S., degrees. The need to properly train men who would be responsible for the dairy instruction of the future was recognized, as well as the need for maintaining university teaching at levels greater than that needed by short course students. The early recognition of these problems was to carry extreme influence upon teaching developments for years to come.

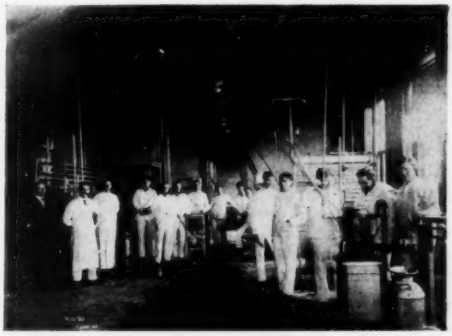

Fig. 1. Reproduction of picture taken in 1908 of a class in dairying taught by J. H. Frandsen, first editor of the *Journal of Dairy Science*.

As the field of dairy manufacturing began to grow, new problems appeared. The rapid increase in attendance at all agricultural colleges raised the question of how to handle large numbers of students in laboratory work. It also became apparent that efficient instruction in dairy work required abundant and expensive equipment, together with more instructors in proportion to the students. Another problem was how much purely practical work a student in dairying should be given and what parts of his time should be devoted to securing a scientific training fundamental to the work for which he was preparing himself. Was it the duty of a Dairy Department to turn out men qualified to operate a business enterprise or was it their job to give men a good fundamental training and expect them to gain most of their practical

experience after leaving the institution? Opinions of course differed, but as time progressed the tendency for the colleges was to adopt the philosophy that more credit to the institution and more service to the state would be derived by turning out a few thoroughly qualified men who would become leaders in their line than by graduating more students who could immediately turn their hands to practical work, but whose training had been inadequate to enable them to do real constructive work of permanent value.

This attitude has proven to be sound, although perhaps it has been too complacent. Had a more aggressive approach been followed, more good students might have been encouraged to enter the field of dairy manufactures.

Introduction of More Scientific and Less Agricultural Subject Matter (1920-1950)

During the period 1925 to 1935, teachers concerned themselves with such problems as trends in instruction, seminars, value of practical experience, the importance of the college creamery, placement, factors in knowledge retention, objectives, degree of specialization, individualized instruction, crowded schedules, and character training. Out of this came the conclusion that many means might be employed in teaching dairy manufactures but that the most persuasive influence was the personality, ability, and integrity of the teacher.

"No written work, no spoken plea,
Can teach men's hearts what they should be;
Not all the books upon the shelves,
But what the teachers are themselves."

During this period, the need for teachers with executive, teaching, and research ability was apparent. In teaching dairy manufacturing, some instructors have gained prestige and rendered service as administrators, others through their ability to disseminate information, and still others through their research findings.

The era of the introduction of more scientific and less agricultural subject matter was initiated when the American Dairy Science Association, recognizing the many problems being encountered in the teaching of dairying, made a study during the period of 1937 to 1942 of the teaching problems and needs encountered during the first 30 years of its existence. A large percentage of the members involved in teaching were asked to consolidate their thinking to serve as a guide for charting the teaching needs of the future. This was accomplished by appointing a general curricula committee and sub-committee in Dairy Production and Dairy Manufacturing. The members of the Dairy Manufacturing sub-committee were not in complete agreement as to agricultural background needs. The majority felt, however, that dairy manufacturing was as closely allied with economics, science, and business as with agriculture and that very few strictly agricultural courses were essential. All members felt that the basic sciences of mathematics, chemistry, physics, botany, and zoology were important; that courses in English, economics, agriculture, biochemistry, and bacteriology should be included along with the specific dairy manufacturing courses, and that such courses as economics, history, psychology, accounting, and engineering could be offered as either required or elective courses.

For the benefit of future dairy manufacturing teaching, it was important that most of the committee felt that a liberal number of electives should be permitted, especially after the first 2 years, and that the student who intended to follow the business or sales phase of dairy manufacturing would not ordinarily elect the same courses as that of a student who intended to be a dairy scientist. It was thought that having dairy subjects taught in the freshman year, particularly principles of dairying, was desirable and with the aim to provide a dairy manufacturing subject each term, although this would be difficult for schools operating on the quarter system. The committee hesitated to recommend the amount of time to devote to each course, since in some cases it might be logical to combine the study of two products in one course, depending on the importance of the products in the state. It was felt that the dairy manufacturing curriculum proposed by the committee afforded the student a liberal education because of the number of elective credits provided. Neither was the curriculum too specialized, since the dairy manufacturing subjects accounted for only 17.7% of the total credits offered.

The curricula proposed were to aid in accomplishing the following objectives desired in teaching dairy manufacturing:

1. To give the student an appreciation of the importance of the dairy industry and its relationship to other branches of industry and an understanding of the problems involved in the production, manufacturing, and marketing of dairy products of high quality.
2. To develop in the student such skill in the technique of manufacturing dairy products and in the management of dairy plants that he can render satisfactory immediate service and advance to responsible positions in various dairy organizations.
3. To provide the student with basic training in dairy science and in such fundamental sciences as chemistry, bacteriology, physics, and mathematics, which are essential in the analysis and solution of technical manufacturing problems.
4. To provide training in such subjects as economics, business, sociology, psychology, English, journalism, and public speaking, which

will prepare the student for executive work and for well-rounded service in the dairy manufacturing industry and in the community.

5. To create in the student a desire for more knowledge so that he may continue to search for further information after having completed his college course, since it is only through keeping in touch with modern developments in his field that he will be able to render satisfactory service in this rapidly advancing industry.
6. To discover the student of unusual ability and aptitude for research or teaching and encourage him to pursue graduate work so that the general industry may be benefited by having men of superior ability become the leaders in teaching and research.
7. To so conduct research that the graduate student may be able to see the enormous opportunities that lie ahead of him and to inspire him to enter the field of research and education with enthusiasm and vigor.
8. To develop a well rounded personality with emphasis on such qualities as integrity, cooperation, loyalty, and responsibility.
9. To offer courses that will aid agricultural students majoring in such fields as dairy extension, production, high school instruction, and others.

The committee recognized the value of practical experience by proposing a summer practice course to be taken preferably in the college creamery and to consist of spending a few days in each of the operating departments, listening to lectures, and working in a laboratory devoted to dairy plant management. In addition there would be survey tours of dairy plants, laboratories, health departments, and dairy equipment distributors.

The above ideas have aided in guiding the teaching of dairy manufacturing during the past 10 or 15 years, although unanimous agreement on any one approach has not been achieved. The demand for graduates has been for different types of minds and minds trained along a variety of different lines. It is quite evident that recognizing the need for flexibility of the curriculum to provide a combination of courses which best fits the student's particular aptitude and the introduction of more scientific and less agricultural subject matter have been valuable steps in the progress of teaching dairy manufacturing.

As the result of the incorporation in the curriculum of many courses in the basic sciences, the nomenclature "dairy technology" and "dairy technologist" originated and have been used in many schools to designate dairy manufacturing sections, departments, and curricula.

The Present Era

At present, we are undoubtedly shifting into the functional approach to teaching dairy manufacturing subjects, leaving the student free for either business or technical specialization. Some schools, attempting to modernize their teaching program, have already replaced the traditional product approach by the teaching of functions that are common to the manufacture of all products. This indicates that a new era in teaching dairy manufacturing is definitely here and that the present trend will be adopted in most of the large universities before many years. The functional approach places more emphasis on acquainting the student with the basic principles involved in food processing, leaving more time for training in the basic sciences, business administration, or other courses, depending upon the major interests and aptitude of the student and more nearly meeting the demands that are likely to be made of the dairy manufacturing graduate of the future.

Any curriculum is likely to become inadequate with new developments, and there may be need for constant revision yet maintaining flexibility for a thorough training in the fundamental sciences and affording thorough basic knowledge of the products of the industry along with fundamentals of business, human relations, and leadership. Technical knowledge alone is not enough to satisfy industry demands, and a well rounded knowledge of the skills of all jobs of the industry is expected. This objective will surely be achieved, partly through responsibility assumed by industry to supplement technical training.

As has been the experience in the past, the caliber of the teaching staff may be expected to play an important role in the success of any teaching program even to the extent of counseling, advising, and aiding in maintaining the dignity, prestige, and morale of those employed in the industry.

The Dairy Products National Trade Associations

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The dairy products trade associations during the past 50 years have aided immeasurably in the progress of the dairy industry of this nation. Their contributions in many instances have served as a part of the foundation upon which the different segments of the industry have grown and developed. The technological improvements made during the last half-century are a memorable tribute to the constructive thinking and wisdom, careful planning, organization, forethought, tolerance, understanding, and unselfish cooperation on the part of many individuals and organizations working together for a common objective.

W. H. E. Reid

The American Butter Institute

The American Butter Institute was founded in Chicago, Ill., on May 28, 1908. The early name of the organization was The National Association of Creamery Butter Manufacturers.

The following persons were called to a meeting at the Grand Pacific Hotel through invitations by J. H. Rushton and G. E. Haskell: J. A. Walker, H. A. Page, F. J. Herrick, H. S. Johnson, W. T. S. White, W. A. Tilden, G. L. Hubbell, and A. S. Hanford. In the organization meeting Mr. Rushton was elected chairman and Mr. Hubbell secretary.

Mr. Rushton stated that the objects of the meeting were to exchange views and secure information concerning all matters tending to promote the growth of the dairy industry in the United States; to study the world's markets and outlets for creamery butter, and to consider further the feasibility of an organization whose objects should be to gather statistics concerning said industry; to improve the quality of the butter made in the United States, as well as the methods of handling and manufacture; and to consider all matters connected with increasing the production of butter in the United States.

The first secretary of the organization was G. L. McKay. The name of the organization was changed to American Butter Institute in 1937. Secretaries or executive secretaries following McKay were: W. F. Jensen, N. W. Hepburn, H. A. Ruehe, and Russell Fifer, who was appointed on August 15, 1945, and is still serving. Other officers for 1956 are: president, Henry F. Specht; and vice-president, Erhart D. Edquist. At the present time the Institute has a membership of about 150 companies who operate approximately 350 creameries.

The major activity of the American Butter Institute is to represent the butter manufacturing industry in legislative matters and before federal administrative agencies. Activities in the various states are instituted only upon requests from the members or respective state industry associations.

Considerable emphasis is placed upon activities relating to the improvement in the quality of cream and butter. A Cream Quality Manual has been published to serve as a reference guide to the industry and is used as a textbook in vocational agriculture classes in several states. In 1953 the Institute appointed a liaison committee which meets frequently with top officials of the U. S. Food and Drug Administration in Washington. This work has resulted in full-can filtering methods for cream, which have brought about improvement in quality in respect to extraneous material. Also, a closer correlation of grades of cream has been made possible by state-sponsored grading schools instigated by the state regulatory agency and aided by federal food and drug officials and the butter industry.

The Institute provided a laboratory service to members for many years. Presently, arrangements have been made with the laboratory of the American Dry Milk Institute to carry on this service at a nominal cost. Other important activities of the institute are:

1. Filing of briefs and appearances before the ICC and other traffic regulatory bodies with respect to freight rates, icing charges, and demurrage.
2. Investigation of new tests for ascertaining the quality of butter and improved methods for processing.
3. Encouragement of grassland farming to help lower the cost of milk production.
4. Working with other butter organizations to assist the American Dairy Association and National Dairy Council with respect to advertising, merchandising, and the promotion of butter, and in certain fundamental research on butter and butterfat.

Active committees of the American Butter Institute, which meet frequently and upon call of the committee chairmen, include: Cream Quality and Production, Research, Sales Promotion and Publicity, Industrial, Traffic, Butter Standards, and Food and Drug Liaison.

Members of the Institute process 40% of the total creamery butter manufactured and distribute about 75% of the creamery butter produced in the U.S.A.

The National Cheese Institute

The National Cheese Institute, Inc., was organized in 1927. The first officers were: president, J. H. Wheeler; first vice-president, H. G. Davis; second vice-president, J. J. Gerber; third vice-president, Frank R. Pentlarge; treasurer, Frank Schujahn; and secretary, John D. Jones, Jr.

The objectives of the Institute are to establish a common ground upon which its members may meet for consideration of problems concerning the welfare of the industry; to aid in the development of a sound industry; to assist the members in the daily conduct of their business; to facilitate the gathering of specific data and statistics pertinent to the industry; and to keep the members informed on matters of concern to the industry.

Officers of the Institute for 1955-56: president, W. H. Pauly; first vice-president, J. J. Gaffney; second vice-president, W. P. Ayres; third vice-president, J. C. Loftis; fourth vice-president, V. R. Butler; treasurer, C. E. Zuercher, and executive secretary, E. W. Gaumnitz. The number of members when the association was organized was 18. At present there are 86 active and 42 associate members.

One of the major accomplishments of the Institute was the promulgation in August, 1950, of definitions and standards of identity by the Food and Drug Administration for 36 individual varieties of cheese, eight general classes of cheese and six categories of cheese and related products. The Research and Quality Committees of the Institute have taken an active part in the progress in the quality, packaging, and merchandising of cheese, which is a notable accomplishment.

The Milk Industry Foundation

The International Milk Dealers' Association (predecessor organization) was formed in 1908 in Chicago as an outgrowth of an acquaintance made by a few dealers while attending the National Dairy Show. The Milk Industry Foundation was organized by the International Milk Dealers' Association in 1935 as a public relations organization. These organizations were merged in 1946. The first officers of the International Milk Dealers' Association were: president, J. D. Nichols; vice-president, Loton Horton; secretary-treasurer, B. D. White.

The objectives of the Milk Industry Foundation, as stated in their by-laws, are "to develop and promote increased consumption of the products of the milk industry; to collect and disseminate such accurate information pertaining to the milk industry as may be of mutual benefit to its members and to the public; to assist members, producers, and others to the end that production and distribution costs may be lowered and quality of product improved; to inculcate and maintain principles of fair dealing between members, producers and the public; to promote the welfare of the bottled milk industry; to cooperate with other branches of the dairy industry in furtherance of the advancement of the industry as a whole; to strive for maintenance of the free enterprise system as our contribution to the improvement of the American economy; and to do all other lawful acts and things incidental, necessary or convenient to accomplish the objectives and purposes herein set forth."

Through the Foundation the fluid milk dealer finds expression and leadership. Members and affiliates can be found in the United States, Argentina, Australia, Canada, Cuba, England, Italy, Japan, Netherlands, Norway, Sweden, and Venezuela.

The Milk Industry Foundation is at the crossroads of communications. It provides a "listening port" for the milk industry. Its services range from the handling of individual requests from members to the completion of important industry programs connected with the Department of Agriculture and other government agencies. The officers of the Milk Industry Foundation for 1956 are: president, C. Raymond Brock; vice-president, Hubert Garrecht; secretary, Gilbert H. Hood, Jr.; treasurer, E. J. Mather; and executive director, Richard J. Werner.

The number of members at the time of the organization of the International Milk Dealers' Association was 12. The present membership of the Milk Industry Foundation is 1,537.

The major accomplishments of the International Milk Dealers' Association and the Milk Industry Foundation over the last 50 years include the standardization work on milk equipment; the publication of the Accounting Manual, the Plant Manual, and Laboratory Manual for milk processors; the initiation in 1951 of a Sales Training Institute for members; the initiation of a periodical study of milk distribution costs; a study of the status of college dairy students (1955); the inauguration of annual advertising contests; the launching of a safety program to help members improve employee safety in the plant and on the route; the institution of statewide coordinated sales promotion campaigns; coordinated research activities designed to interpret scientific research to members of the industry; the annual publication of *Milk Facts;* and an industry-wide public relations program. This program includes:

Pasteur awards. Every year the Foundation presents an award for heroism or distinguished public service performed in line of duty. These awards are made without regard to company membership in the Foundation or to the recipient's position in his company. Any person in the milk business may be nominated to receive an award for heroic or meritorious service taking place during business operations.

Advertising contest and awards. Recognizing the tremendous impact of advertising in the

economy today, the Foundation sponsors an annual advertising contest and review during its convention. Each company submitting a winning entry is presented with a certificate for meritorious advertising.

Agricultural leadership awards. The Foundation's agricultural leadership awards are made each year to a number of outstanding senior students of dairy science in the agricultural colleges. Selections are based on initiative, leadership, and scholarship during the first 3 years of college. U. S. and Canadian students are eligible for nomination.

Sales Training Institute. This activity was planned to improve selling and supervision, to provide better employee relations, and to increase the sale of milk and its products.

The International Association of Ice Cream Manufacturers

In 1900 the Three I's Association, namely, Iowa, Illinois, and Indiana, was organized, and in 1902 its name was changed to the Central States Ice Cream Manufacturers Association. In 1906 the National Association of Ice Cream Manufacturers was formed. Because of the increasing number of members of the Association in Canada and foreign countries, in 1927 the word National was changed to International. In 1935 its affiliate, the Ice Cream Merchandising Institute, was organized and in 1936 G. W. Hennerich became its managing director. The Institute is an educational organization affiliated with the International Association of Ice Cream Manufacturers, chartered as a separate corporate entity, the purpose of which is to provide members with the finest possible sales and merchandising program.

J. H. Frank was the first president of the Association. The first full-time paid secretary was Fred Rasmussen, who served from 1925 until his death in 1932. He was succeeded by R. C. Hibben, the present executive secretary. Other officers for 1955-56 are: president, Hugh F. Hutchinson; vice-president, Robert H. Reeves; treasurer, I. N. Hagan; and assistant treasurer, Paul B. Beck.

In 1907 there were 216 members. By August 31, 1955, the number had grown to 2,364.

The progress and accomplishments of the International Association of Ice Cream Manufacturers are set forth in its booklet, "50 Years of Progress." During that period the Association instituted its first plant sanitation program; formulated industry standards and regulations; prepared an accounting system for the industry; organized a sales managers' council; formed a production and laboratory council; formed the Ice Cream Merchandising Institute; and originated a public relations program.

The Association has continued its aggressive program through all of its various departments in a constructive effort to serve the consumers of ice cream, the manufacturers, producers, educational institutions, and other agencies associated directly or indirectly with the ice cream industry.

The American Dry Milk Institute

The plan for the American Dry Milk Institute was conceived by a group of dry milk manufacturers attending the National Dairy Show in 1924. On June 3, 1925, the formal organization of the Institute was announced. C. E. Gray was the first chairman, and he continued in this capacity until his death in 1944. Because of his sincerity of purpose, the manner in which he gained the confidence and cooperation of others, and his ability to apply scientific data to practical uses Mr. Gray won the love and esteem of members of the dairy industry throughout the world. His innumerable contributions will have an everlasting influence on the industry to which he devoted his life.

The first vice-chairman of the board of directors was R. G. Soule and the first secretary-treasurer was M. J. Metzger. H. E. Van Norman served as the first executive officer until the fall of 1928 when he was succeeded by Roud McCann.

The American Dry Milk Institute, through its various committees—and especially through its War Assistance Committee organized during the second world war—has worked consistently and in a highly cooperative manner with various federal agencies, such as the U. S. Department of Agriculture, the War Production Board, the federal War Food Administration, and the Armed Forces QMC Division; with universities and colleges, and with dairy trade associations.

The officers of the Institute for 1956 are: chairman of the board of directors, T. G. Stitts; vice-chairman of the board, R. M. Hadrath; secretary-treasurer, M. R. Debaets; and director, B. W. Fairbanks.

The American Dry Milk Institute aims are to instigate and conduct research on the nature, composition, and use of dry milk; to compile, evaluate, and disseminate useful information on these subjects; to aid in further improving the high quality of dry milks; to assist and guide consumers in making the most efficient and economical utilization of dry milks; and through every available means to work with manufacturers in maintaining and enlarging present markets and in developing new ones.

The benefits of the findings of the Institute's research efforts have been passed not only to its membership but to the users of dry milks as well. One-hundred-and-one projects have been fostered by the Institute, which indicates its appreciation of the value of research and procedure to dry milk manufacturers.

The American Dry Milk Institute had the distinction of winning the Grand Award of the American Trade Association executives for the year 1956 in recognition of its stable ferment

process and for rendering outstanding services to the industry which it represents as well as to the American people.

National Association of Retail Ice Cream Manufacturers

The National Association of Retail Ice Cream Manufacturers was organized in August, 1933. The first officers of the Association were: president, Irving C. Reynolds; vice-president, Phil C. Barber; and secretary-treasurer, Roy I. Brown.

The Association was established to foster a spirit of unity, good will, and cooperation among retail ice cream manufacturers of the United States, to the ends that unfair trade practices may be eliminated and that better business methods, practices, and policies may be inaugurated and maintained. The organization strives to assure concerted action on all matters affecting the dairy and ice cream industry; to achieve a competition that is honorable, just, and reasonable; and to provide for the general uplift of the industry with due regard to public welfare.

The present officers are: president, Lloyd A. Greene; first vice-president, Frank A. Maharg, Jr.; secretary, Carl H. Lindner; treasurer, Forrest L. Mock; and executive secretary, E. M. Warder. At the time of the organization of the Association there were 44 members. The present membership is approximately 600.

Some of the major accomplishments of the Association during the past 20 years are: the firm establishment and maintenance of a trade organization representing the manufacturers who sell their products through their own retail outlets; the development and maintenance of a program embracing public meetings (conferences and conventions), member information service (bulletins and annual publications), and specialized service to individual members on business operating problems including legislative service; and the development and maintenance of a fine cooperative relationship in the ice cream and dairy industry as a whole.

Evaporated Milk Association

The Evaporated Milk Association was established in August, 1923, with 21 members. The first officers were: chairman, L. R. Hardenbergh; vice-chairman, C. T. Lee; treasurer, E. G. Annell; and executive secretary, H. C. Hooks. The officers of the Association for 1956 are: president, E. S. Hartwick; vice-president, G. B. Page; treasurer, C. E. Pierce; and executive secretary, E. H. Parfitt. There are now 26 members.

The chief accomplishments of the Association during the past 30 years include:

1. Institution of medical and nutrition research that proved the value of evaporated milk for infant feeding, feeding the aged, and for allergy and special dietary management.
2. Inauguration of the first test kitchen in the industry in which a home economics staff conducted research to discover the advantages of evaporated milk in food preparation and to develop recipes for consumer use.
3. Introduction of an industry-wide voluntary sanitary standards program.
4. Establishment of a continuing education program by development of publications, films and filmstrips, charts, and posters for use by professional workers in the medical, health, and welfare fields, in education, and in home economics.
5. Establishment of editorial services including food photographs for food editors of newspapers and magazines, subsequently expanded to include broadcasters of women's interest programs on radio and television.
6. Establishment of an Administrative Technologists Committee to promote research on evaporated milk at colleges and by the U. S. Department of Agriculture. This has resulted in research work on heated milks, including the effect of heat on the whey proteins.

Dairy Industry Supply Association

The Dairy Industry Supply Association was formally incorporated in New York in 1912 as the National Association of Ice Cream Supply Men. In 1926 this became the Dairy and Ice Cream Machinery and Supplies Association, and in 1939 the present name was adopted. The first officers were: Olivar D. Jordan, Roberts Everett, and Charles W. Caldwell.

Among the aims of the first organization were an interchange of trade tips, the staging of very small displays in hotel lobbies, and efforts to assure adequate hotel accommodations for the traveling salesmen of that era. The present objective of the Association is the advancement of the interests of dairy industrial suppliers and equippers by strengthening the wide markets which they serve. Since these markets influence the health and welfare of all the public, the Association frequently is able to add wide public service to its objectives.

The present officers of this organization are: president, L. N. Lucas; vice-president, S. E. Crofts; treasurer, R. E. Cairns; and executive vice-president, Roberts Everett. Today there are more than 400 members in this organization.

Among the major accomplishments of DISA during the past 40 years are: sponsoring jointly with the A.D.S.A. since 1930 the Collegiate Students' International Contest in Judging Dairy Products and the educational fellowship program; originating, in 1926, the Dairy Industries Exposition, the world's largest regularly held trade show; cooperating in development of 3-A Sanitary Standards; serving as peacetime "forum" for suppliers and equippers, but assuming in wartime and other times of national emergency the role of spokesmen for the needs of the dairy processing industries;

and establishing, in 1920, one of the first "Fair Practices" codes in any United States industry.

National Ice Cream Mix Association

The National Ice Cream Mix Association was organized in 1945, the first officers being: president, Victor Berghoefer; vice-president, Merle W. Hart; treasurer, Gorman Prince; and secretary, Henry Kohler. The objectives of the Association are to promote the welfare and sales of the ice cream mix industry and to maintain vigilance of the activities of government agencies and legislation pending or approved.

The present officers are: president, Carl E. Greiner; first vice-president, L. S. Hollinger; second vice-president, Keith Burden; third vice-president, Harry Jollie; secretary, A. A. Bluemke; treasurer, R. P. Galloway; and executive vice-president, E. L. Koepenick.

The major accomplishments of the Association during the last 10 years are: bringing about favorable changes in wartime government regulations and representation of the industry at hearings in Washington, D. C., on standards of identity for frozen dairy products.

The membership of the Association when established was 1,000 and included ice cream wholesalers and manufacturers of "soft-serv" products. Today's membership of 76 includes only ice cream mix manufacturers.

Soft-Serv Frozen Dairy Foods Association

The Soft-Serv Frozen Dairy Foods Association was organized in 1955. The officers are: president, Robert Hepler; vice-president, Charles Russo; secretary-treasurer, John F. Vaffis; and executive secretary, Harry J. Kimpel. The objectives of the organization are: publishing this industry's first trade magazine, "Soft-Serv Digest"; the establishment of Soft-Serv short courses; and conducting state conventions. There are 250 members.

The Future of the Trade Associations

The national, international, and state dairy products trade associations have made many constructive and worth-while contributions to the dairy industry of this nation during the past 50 years. These contributions resolve themselves into many classifications; in general, they represent unselfish, cooperative efforts in the search for new knowledge and in the application of efficient business principles so as to be of greater service to producers, processors, and the consuming public. The momentum gained from the activities of the past 50 years should lead the dairy products trade associations to seek even greater achievements during the years ahead.

Significant Developments in the Distribution and Pricing of Market Milk in the United States, 1906-1956

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Food distribution in general and milk distribution in particular are among our most stable industries. It is only when we occasionally pause to review their progress that we realize how much they have changed in the last 10, 25, or 50 years. It seems logical to discuss these developments under several headings, namely: Sales and Consumption Trends; Technological Developments; Changes in Marketing Organization and Methods; Pricing Arrangements; and Public Control.

Leland Spencer

Sales and Consumption Trends

Total sales and consumption of fluid milk and cream have increased gradually but significantly during the last 50 years and, in fact, for a much longer time. The quantity of milk used for these purposes in 1955 is estimated at 58 billion pounds, 85% more than was consumed in 1909, the earliest year for which data are available *(10)*. Most of the increase in consumption of milk and cream has been due to the steady growth of population, which rose from 92 million in 1909 to 165 million in 1955.

Milk consumption by farm families has declined because fewer people now live on farms. There has also been a marked reduction in the quantity of milk distributed by producer-dealers. Thus, commercial milk distributors probably marketed at least twice as much fluid milk and cream in 1955 as they did 50 years ago.

The quantity of fluid milk and milk equivalent of fluid cream used per person changed only from 343 lb. in 1909 to 352 lb. in 1955. Data are not available for milk and cream separately, but we know that the consumption of whole milk has increased more than the combined figures indicate while cream consumption has declined. In recent years there has been a striking increase in sales of skimmilk and skimmilk drinks, which no doubt has detracted somewhat from the potential sales of whole milk. At the same time, sales of special high-fat milks have declined. Another evidence of the efforts consumers are making to limit their consumption of milk fat (and other animal fats) is the rising popularity of half-and-half as a substitute for cream.

Although efforts are constantly being made to develop and merchandise products such as evaporated milk, concentrated milk, and dried milks as partial substitutes for fresh fluid milk, none of these products has won general consumer acceptance. Fluid milk continues to be one of the most generally used and most highly regarded of all foods.

Before 1910 or thereabouts, there was little advertising of milk or cream and no organized programs for persuading consumers to use more of these products. Today there is a vast amount of advertising of milk and milk products by milk dealers and cooperatives, and there are two industry-supported organizations (National Dairy Council and its affiliated units, and American Dairy Association) which also spend millions of dollars annually in efforts to increase the consumption of these products.

Technological Developments

This paper will deal mainly with economic changes in the milk industry, but some attention must be given to important developments in the technology of milk handling, processing, packaging, and delivery. These technological changes have had very significant effects upon marketing organization, methods, and practices.

Among the important technological changes in the milk industry during the last 50 years, we think especially of the following:

Pasteurization. There has been almost a complete shift from raw milk to pasteurized milk throughout the United States since 1906.

Homogenization. This has developed principally since World War II. Now a major part of the milk sold in many cities throughout the country is homogenized, and most of it is fortified with Vitamin D.

Packaging. At the beginning of the period under review, most milk was dipped or poured into the customer's pail or pitcher. The sale of dipped milk at stores in New York City continued until 1933, but in most places bottling was the rule much earlier. Then, in the early 1930's, a few dairies began to distribute milk in paper containers on a large scale. The use of these lightweight nonreturnable containers has increased steadily. In many markets today as much milk is packaged in paper as in glass, mainly for distribution through stores, restaurants, and schools. The quantity of loose or dipped milk sold is now insignificant.

Labor-saving, quality-protecting equipment. Technological changes associated with quality protection and the saving of labor have called

for a great increase in the amount of investment in plants and equipment. Modern pasteurizing plants require such equipment as weigh cans with recording scales; automatic can washers; pasteurizers, coolers, and heat-exchangers with automatic controls; insulated holding tanks; automatic bottle fillers and washers; automatic steam generators and mechanically-fired boilers; mechanical refrigeration equipment; pipe lines and valves; pumps, motors, and power conveyors. Most of the equipment through which the milk passes is now made of stainless steel.

This is a convenient place to mention also the replacement by motor trucks of horse-drawn milk-collecting and delivery equipment. The use of delivery trucks with refrigerated bodies is spreading over the country. Tank trucks have become the principal means of moving milk from plant to plant. The collection of milk from farms by tank trucks, though still in its infancy, is increasing rapidly.

The higher investment in plant and equipment has raised the level of fixed costs but has significantly reduced the amount of labor required for handling, processing, and packaging milk.

Marketing Organization and Methods

At the beginning of the 50-year period under review, a large percentage of the milk used in fluid form was distributed by producers and most of the remainder by small dealers who operated only one or a few delivery routes. Milk plants were small and numerous. There was little pasteurizing or bottling. Milk was delivered every day, usually early in the morning, and sometimes twice a day, since the milk was unpasteurized and family refrigerators were uncommon. In most places, stores handled milk only in small quantities as an accommodation. There were no giant dairy companies, no milk producers' bargaining associations of importance, few specialized processors or subdealers, no vending machines, and no milk distributed in schools. Much of the work in milk plants and on routes was done by the proprietors and members of their families, rather than by hired workers. Dairy employees were not unionized.

Now all these conditions are pretty much reversed. Suppose we list the principal changes in marketing organization and methods that have taken place during this 50-year period with some explanatory comments.

Fewer and larger plants. The increased use of expensive equipment that has been mentioned previously has substantially raised the optimum size of plant. The replacement of horse-drawn equipment by motor trucks and the use of lightweight paper containers have made it possible for each plant to serve a more extensive area. Many pasteurizing plants are supplying bottled milk to towns 10, 20, or even 50 miles away; in a few exceptional cases, paper-packaged milk is hauled to markets as far as 100 to 500 miles from the place of pasteurization and packaging.

With more milk being hauled directly from the farms to city plants, country receiving plants have been greatly reduced in number. This trend is being further accentuated now that more and more milk is being collected from the farms by tank trucks.

Fewer and larger distributors. There has been a definite tendency for a few of the larger firms in each market—the Big Three or Big Four, for example—to acquire control of the major part of the business. At the same time the number of smaller distributors has declined. Producer-distributors have decreased almost to the vanishing point in many areas. Thus, the competitive base in most milk markets has been narrowed appreciably.

Large-scale chain dairy companies. One of the most striking developments in dairy organization during the last 30 years has been the growth of large firms with subsidiaries or divisions operating in many markets. This has been accomplished mainly through purchase by holding companies and other large firms of established local or regional businesses. Four of these large organizations—National Dairy, Borden, Foremost, and Beatrice—have become practically nationwide in their operations. Four others—Arden, Carnation, Fairmont, and Pet—have extensive regional chains. Altogether the "Big Eight" probably control close to 40% of the national distribution of fluid milk and cream. This, to be sure, represents considerably less concentration than has occurred in the marketing of cheese, canned milk, or ice cream, but the trend is significant.

All of these large-scale dairy firms have diversified operations, including the manufacture or distribution of a wide range of dairy products. Some also produce or distribute such nondairy products as dog food, salad dressing, instant coffee, frozen foods, and chemicals.

The large-scale chain dairy companies have done much to improve and standardize quality and to set higher standards in plants, equipment, and operating procedures, especially in areas where the local industry was not progressive. They have obvious advantages in obtaining capital; in purchasing equipment, containers, and other supplies; in maintaining research and quality control laboratories; in engineering, and in advertising. On the other hand, they are handicapped in dealing with labor.

Although none of these chain organizations has achieved a dominant or monopolistic position in the milk industry, their continued growth and the tendency toward consolidation among them is beginning to raise serious questions of public policy toward safeguarding the competitive structure of dairy markets. The large chain dairies are frequently under attack by

congressional committees, the Federal Trade Commission, or the Department of Justice.

Milk distribution by cooperatives. Cooperative organizations of milk producers have been most active in the field of bargaining but some have become important in the handling and distribution of milk. Many of the associations that began as bargaining cooperatives later acquired country receiving plants and plants for converting surplus milk into manufactured products. They did this mainly to strengthen their bargaining position. Some associations have acquired ownership of pasteurizing and bottling plants and route systems for delivering milk to retail or wholesale customers. Some of these cooperative enterprises are of substantial size. The Dairymen's League, for example, ranks as the third largest distributor of milk in the New York City market and also is one of the principal distributors in Buffalo, Rochester, Syracuse, Utica, Troy, Poughkeepsie, and other secondary markets. Other cooperatives that are prominent in milk distribution include the United Farmers of New England, the Cooperative Pure Milk Association of Cincinnati, and the Challenge Cream and Butter Association of California.

From a national viewpoint, however, milk distribution by cooperatives does not seem to be expanding rapidly, and it is not feared as much by proprietary distributors as it was in the 1920's or 1930's. Cooperatives have some advantage over proprietary firms with respect to exemption from taxes on undistributed earnings, but this may be partly or wholly offset by inherent weaknesses of democratic control of such operations as the distribution of milk. Many bargaining associations have refrained from going into the distribution end of the business because they felt this would impair their effectiveness in bargaining.

Specialized marketing agencies. Typically, the fluid milk industry has been characterized by an integrated form of organization—with a single agency, the milk dealer, performing all marketing functions, beginning with the collection of milk from farmers and ending with the delivery of the milk to the consumer's doorstep. But this characteristic form of organization is giving way in many places to the performance of different marketing services by separate agencies. Much of the country handling of milk is now done by cooperative or proprietary firms that do not have milk pasteurizing plants or delivery systems of their own. Similarly, many firms that operate pasteurizing and bottling plants neither have their own country receiving plants nor operate their own delivery routes. They are generally known as processors. In some areas, such as northern New Jersey, there are literally hundreds of self-employed deliverymen, called subdealers or bob-tailers, who purchase bottled milk from processors and deliver it to retail and wholesale customers.

Self-employed subdealers seem to have a great advantage over unionized deliverymen in getting and holding customers and building up their loads. Subdealer routes often carry 25 to 50% more product than routes operated by hired drivers.

Store distribution. Up to 1920 or thereabouts, regular daily delivery to homes was the almost universal method of distributing milk for home consumption.[1] Then, a little more than 30 years ago, certain food chains began to take a special interest in milk and to push its sale as a leader. Since then, store distribution has grown steadily and an increasing percentage of the milk supply has been marketed in this way. The shift from home delivery to store distribution has been particularly rapid in some of the large cities, such as New York, Chicago, Los Angeles, and San Francisco. At present, nearly three-fourths of the milk distributed for home consumption in the New York City market is sold by retail food stores *(7)*. In the Minneapolis–St. Paul market, wholesale distribution (mainly to stores) increased from 52% of the total volume in 1950 to 57% in 1954 *(8)*. During the last 3 years, store distribution in many of the smaller markets has increased from about 15 to 20% of the supply to 35% or more.

The fact that some of the chain store organizations have featured milk and pushed its sale as a leader, often at significantly lower prices than are charged for home delivery, is an important reason for the swing from home delivery to store distribution. Other factors that have contributed to this trend were: the growth of large cities, unsound pricing on the part of retail dealers, and rising labor costs without comparable gains in daily output of retail routes. In the larger cities, wholesale milk routes that make deliveries to stores usually carry from three to five times as much milk as the typical retail route, yet each is operated by one man. Consequently, a given increase in wages or fringe benefits adds more than twice as much to the unit cost of delivery to the home as it does to the unit cost of serving stores.

It was inevitable that stores would become an important agency for the distribution of milk. But retail milk dealers have unwittingly encouraged the trend by failing to grant quantity discounts in keeping with the lower unit cost of serving the larger customers. It is true that many dealers are now giving quantity discounts, but mostly they are "too little and too late."

Every-other-day delivery. By far the most important step taken toward reducing the cost of home delivery during the last 50 years has been the switch to every-other-day service. This system was introduced early in World War II mainly for the purpose of conserving tires and

[1] New York City was an exception. There a large volume of dipped milk, priced about 4 cents a quart lower than bottled milk, was sold at dairy and grocery stores until 1933.

trucks. It was made effective throughout the nation by order of the Office of Defense Transportation. After the war ended, every-other-day delivery was continued nearly everywhere on a voluntary basis. This brought a significant saving in costs *(1)*, which was not fully apparent because wages and other costs were rising. It is estimated that at the present higher level of wages, retail delivery costs would increase more than 2 cents a quart if daily service were restored.

Sunday operation of most wholesale milk routes has been discontinued and many of the smaller pasteurizing plants have cut their operations from 7 days a week to 5 or 6 days; some do all of their pasteurizing and bottling on alternate days. The adoption of these economical practices helped to offset much of the increase in costs due to higher wages and the change to a 5-day week for dairy employees.

Multiple-quart containers. In many places the use of 2-quart or gallon containers has become important. The Chicago market is an outstanding example of this. In April 1955, one-third of the total volume of milk in Chicago was sold in gallon jugs and a slightly higher proportion in 2-quart packages. Single quarts represented less than 25% of the total volume in April 1955, compared with 59% in April 1949. Some dairies that have made a specialty of distributing milk in 2-quart or gallon containers have been remarkably successful.

The fact that milk in the multiple-quart packages is generally sold at reduced prices has led many to believe that substantial economies could be realized by using these larger containers. The truth is that 2-quart and gallon packages are likely to result in higher rather than in lower costs unless the user can eliminate other sizes. Most dairies must continue to supply milk in 1-quart containers to meet the requirements of their customers, and the addition of 2-quart or gallon packages requires additional investment and extra costs.

The sale of milk in multiple-quart packages at reduced prices is a convenient but expensive way of giving quantity discounts. In most instances, it would be more economical to give suitable quantity discounts to customers who take two or more 1-quart packages at each delivery *(4, 9)*.

The limited evidence available does not indicate that many families prefer the 2-quart or gallon packages of milk or will buy more milk when such packages are used, unless there is a significant saving in price.

Vending machines. Great quantities of gum, candy, cigarettes, and soft drinks have been sold through vending machines during the last 10 years. Milk was a late entry in this class of trade, largely because it is so highly perishable. In the last few years, however, refrigerated vending machines suitable for milk have been developed and their use is expanding rapidly. Indoor vending machines are being placed in office buildings, factories, department stores, schools, railroad and bus stations, airport terminals, and similar places. Large outdoor machines, a more recent development, are being placed near gas stations, at shopping plazas and the like, for the convenience of travelers, local people returning from work, and so on.

The increasing use of vending machines is considered an especially favorable development for the milk industry because they make milk available to consumers at times and places where they would not find it otherwise. Hence, the use of vending machines is expected to bring some increase in consumption.

Milk in schools. About 20 years or more ago, the idea was advanced that the health and vigor of many children could be improved by serving nutritious lunches at school. The federal government and some of the state and local governments appropriated funds to subsidize school lunches. This program was established on a permanent basis in 1946 by the National School Lunch Act. Milk has been included in nearly all of the lunches served under this program. The federal grants for school lunches have to be matched by the states. Last year the total cost of school lunches was close to $600 million, of which the federal government contributed $232 million in cash and donated foods. The remainder of the cost was paid by state and local governments and by the children who paid part of the cost of their lunches.

In 1954, further encouragement was given to the distribution of milk in schools by a federal appropriation of $50 million for a Special School Milk Program. Milk subsidized by this appropriation can be served at any time, even at athletic events. A proposal now before Congress calls for an increase to $75 million in the annual appropriation for the Special School Milk Program. It is estimated that milk served in schools made up more than 2½% of all fluid milk consumed in the United States in 1955 *(5)*.

Pricing Arrangements—Producer Prices

No aspect of the fluid milk industry has undergone greater changes in the last 50 years than the arrangements for setting the prices dealers pay for milk and for distributing the funds to producers *(2)*.

Agencies responsible for price-making. In the first 16 years of this century, it was the universal custom for dealers to pay flat prices for all milk purchased. The pace was set by one or two of the leading dealers in each market. The producers had little or no voice in the process of price-making.

This simple procedure was changed suddenly in 1916-17. Rising costs not compensated for by the payment of higher prices for milk caused the producers to take bold action. In several of the larger city milksheds, the producers perfected cooperative organizations and insisted upon taking over the prerogative of

price-making. Producer strikes were called, and milk was withheld from market until the dealers agreed to the producers' terms. From that time until 1933, collective bargaining was the principal method of establishing the prices dealers paid for market milk.

Between 1929 and 1933, prices of all farm products fell drastically. Milk was no exception. Under the very adverse conditions of the time, with greatly reduced purchasing power of consumers and heavy surpluses, collective bargaining lost effectiveness. Producers were hard hit and extraordinary measures were necessary to relieve their distress. A number of the states and the federal government undertook to restore the incomes of producers by fixing minimum prices to be paid by dealers. The state and federal price-fixing programs begun at that time as emergency measures have been continued with only minor changes to the present day. This public control is not countrywide but it has been extended to cover nearly three-fourths of all market milk. Federal orders are in effect for more than 60 markets in 23 states. Sixteen of the states also have milk control agencies that fix minimum dealer buying prices in some or all markets within their borders.

Federal control of milk prices is being extended to more markets all the time, whereas state control is barely holding its own. The principal purpose of the continuing federal regulation is to stabilize the prices farmers receive for market milk and to protect them from any possible repetition of such a price debacle as occurred in 1931-1933. State milk control programs also have that purpose, but in addition an effort is made to maintain higher prices at all times than would prevail under collective bargaining or open competition.

The federal government has a price-support program for manufacturing milk. This program benefits market milk producers by maintaining higher prices for their surplus milk. In many areas, fluid milk prices also are higher because of this program.

Techniques of pricing. Meanwhile, there have been interesting developments in pricing techniques, such as classified pricing; formula pricing; blending, pooling, and equalization; and seasonal adjustment plans.

Classified pricing. Classified pricing involves the classification of milk according to the forms in which it is used or sold and fixing prices separately for the different classes.

Relatively high prices are fixed for the part of the supply that is distributed as fluid milk and much lower prices for the surplus milk that goes into manufactured products. Surplus milk has to be priced so that the buyers can sell the products made from it in competition with similar products made by unregulated plants in other areas, especially in the great Midwest dairy region.

Classified pricing was introduced by some of the milk producers' associations after World War I. Their purpose was to take full advantage of the inelastic demand for fluid milk and of limitations on the supply of approved milk, both economic and institutional. Today classified pricing is provided for in nearly all federal and state milk marketing orders.

Formula pricing. Another interesting development in pricing techniques is formula pricing. Instead of specifying definite prices for each class of milk, all federal orders now in effect prescribe formulas that are used to calculate the minimum class prices each month. Under some orders the fluid milk (Class I) price is determined by the use of formulas in which economic factors such as feed prices, farm wages, consumer incomes, and the percentage of supply used in fluid sales are the "movers." In other orders, an average of prices paid by milk evaporating plants in the Midwest or the market prices of butter and dried skimmilk are the "movers." In all cases the prices of surplus milk are based on the market prices of manufactured dairy products or on the prices paid by unregulated milk evaporating plants.

Formula pricing of surplus milk was developed during the period of collective bargaining, but the use of formulas for pricing fluid milk was not attempted until later. The federal and state milk orders for the New York City market promulgated in 1938 were the first to include a formula for computing the monthly prices of Class I milk.

The main advantages of formula pricing are that it provides for prompt adjustment of prices as conditions change and saves the trouble and expense of frequent public hearings. Only a few of the major factors that affect milk prices can be included in a formula, however, and their relative importance changes from time to time. Therefore, it is desirable that any formula be reviewed occasionally and modified in accordance with changing conditions.

Price blending, pooling, and equalization. When prices are fixed for different classes of milk, payments are made to producers in one or another of the following ways: *(a)* blended prices based on each dealer's use of the milk he buys; *(b)* pool prices calculated by cooperative associations; or *(c)* uniform prices resulting from what is called market-wide equalization.

Without pooling or equalization, the blended prices paid by the several dealers in a market may differ widely because some use much higher percentages of their supplies in fluid sales than others do. Cooperative pools often include disproportionate quantities of surplus milk and therefore yield returns somewhat lower than the blended prices paid by dealers whose milk goes mostly into fluid sales.

The purpose of market-wide equalization is to eliminate or lessen these disparities in re-

turns to different groups of producers. It is most essential in milksheds that have large surpluses unevenly distributed among the various dealers and cooperatives. Most federal orders provide for market-wide equalization, but most state orders provide for the payment of blended prices by the individual dealers.

Market-wide equalization involves the computation of a single uniform price by a Market Administrator, based on the utilization of milk by all dealers and cooperatives as reported to him at the end of each month. All dealers are required to pay their producers on the basis of this uniform price. Those who sell most of their supply for fluid use owe more for the milk (figured at the minimum class prices) than they pay producers (figured at the uniform price). They are required to pay the difference into an equalization fund.

Similarly, dealers or cooperatives that use a high percentage of their receipts for manufacture pay their producers (figured at the uniform price) more than they owe for the milk (figured at the minimum class prices). They are compensated from the equalization fund for this overpayment.

Unless suitable counter-measures are taken, market-wide equalization tends to attract more milk to a market than is needed for fluid use. One of the most effective counter-measures to prevent the overloading of a market-wide pool would be a quota plan that would allocate to each eligible producer a definite share in the fluid market, deliveries in excess of the quota to be paid for at surplus value.

Seasonal adjustment plans. Dealers, cooperatives, and public milk control agencies have used various devices to encourage producers of market milk to adjust their deliveries seasonally —toward larger deliveries in the fall and smaller deliveries in the spring "flush."

Some incentive for balancing production seasonally is provided by the effect of seasonal changes in the quantity of surplus milk, which brings relatively low prices. Thus, the blended or uniform price is depressed when as much as half the supply goes into surplus uses in May and June and raised when the surplus falls to 25% or less in November. Seasonal differences in the blended or uniform prices can be increased by raising the Class I (fluid milk) price in the fall and lowering it in the spring. It is rather common practice to set the Class I price 1 or 2 cents a quart higher in the fall and winter months than in the spring.

Practically any degree of price inducement desired for seasonal adjustment of production can be provided in this natural way. Some dealers and producer-leaders have objected to seasonal changes in the Class I price, however, on two counts. They dislike seasonal changes in the retail price of milk, which necessarily accompany such changes in the Class I price, and they feel that seasonal changes in the blended or uniform price are not sufficiently regular and assured to have the maximum influence upon producers' decisions with respect to production adjustment.

During the period of collective bargaining, especially between 1918 and 1930, the so-called base-surplus plan came to be widely used. This plan involves the assignment to each producer of a quota based on his deliveries during a specified period, usually in the fall of the year —for example, the months of September-December—and adjusted to represent his share in the fluid market. For that quantity of milk he is entitled to receive a fluid milk price, and for any excess he is paid the surplus value. Under this arrangement, producers have a strong incentive to increase their deliveries during the quota-forming months and to limit their deliveries to the quota level at other times.

Between 1927 and 1933 milk supplies increased generally, and consumption fell (1930-1933). Thus, it became necessary to modify the base-surplus plans and to scale down the producer quotas. Some cooperatives tried to use the plan as a device for limiting production. Instead of allowing their members to establish new quotas each year on the basis of their fall deliveries, they arranged to compute the quotas on the basis of fall averages for two, three, or more years.

The numerous changes in rules for computing bases, together with generally decreasing returns, caused so much dissatisfaction that the base-surplus plans in many markets were discontinued. In the last few years, however, base-surplus plans have been adopted in a number of the federal order markets. The base-surplus plan can be quite effective in stimulating farmers to shift their seasonal patterns of production. It involves some rather difficult administrative problems, however, and has a tendency to bring about an over-all increase in production. Unless it is handled very carefully, the plan may cause production to fall below market needs in the month immediately preceding the quota-forming period.

Another device for seasonal adjustment that has been used in a number of markets since World War II is the so-called "take-out-and-pay-back" or "Louisville plan." This plan calls for withholding a specified portion of the payments due producers for milk delivered in the spring months and using the fund thus accumulated to supplement producer payments in the fall. The take-out-and-pay-back scheme usually is milder in its effect than the base-surplus plan and it involves less difficulty from the standpoint of administration.

One of the objectives sought in using either the base-surplus plan or the take-out-and-pay-back plan is to avoid the necessity for seasonal changes in Class I prices and retail prices. The writer has seen no reliable evidence that stable prices encourage greater consumer purchases than fluctuating prices. Nevertheless, many dealers and producer-leaders consider it desir-

able to avoid seasonal or other changes in the retail price of milk in so far as possible.

Public Control

Public control of the prices dealers pay for milk has already been discussed. This recital of changes in milk pricing and distribution during the last 50 years would be seriously incomplete, however, if some attention were not given to other forms of public regulation affecting this great industry.

Product standards and sanitary control. Fifty years ago, state and local agencies of government were just beginning to achieve success in the enforcement of product standards, control of adulteration such as the watering of milk, and the like. This type of control has been carried to the point where public confidence in the purity of milk, cream, and other milk products leaves little to be desired. The federal government, through the Food and Drug Administration, is now playing an active part in establishing and policing product standards.

Meanwhile, the sanitary quality of market milk and cream has been improved greatly through the combined efforts of the industry and public health authorities. Much new knowledge resulting from research has been used to good effect. A great deal of emphasis in health department regulations concerning milk has been placed upon environmental requirements for dairy farms and plants. One result was a tendency to localize market milk supplies and to impede transfers of milk or cream from one area to another. Recently the emphasis has shifted toward the sanitary quality of the product itself and, with notable exceptions, health department regulations are becoming somewhat less significant as trade barriers. Certain court decisions also have struck heavy blows against unreasonably restrictive regulations.

Licensing and bonding. More than 40 years ago, New York State began to license milk plants and to require dealers buying from producers to furnish bonds to insure full payment. This type of regulation has been taken up by many other states. Likewise, the state departments of agriculture or milk control agencies in quite a number of states have been given responsibility for checking weights and tests to guard against serious errors or fraud in computing the payments due producers.

Fixing retail prices (2). Ten of the 16 states that fix minimum prices to be paid by dealers for milk also fix minimum retail and wholesale prices. At one time, nearly all of the states with milk control laws fixed resale prices, but this phase of price regulation aroused much controversy. Serious difficulties were experienced in trying to enforce the minimum prices fixed for wholesale transactions, especially in markets where the dealers' buying prices were not effectively controlled. The result was that stores and restaurants became the chief beneficiaries of the attempted regulation.

Another criticism of resale price-fixing has been its tendency toward rigidity and toward discouragement of innovations that might yield long-run benefits to consumers and producers. The price-fixing agencies have been especially criticized for refusing to allow stores to sell milk on a cash-carry basis at normal discounts from delivered prices.

The main reason for the fixing of resale prices by state agencies is to prevent destructive price-cutting and price wars among distributors. There is believed to be a real danger that certain dealers, cooperatives, or chain stores may initiate price wars in an effort to obtain a larger share of the market, without regard to the effect upon their immediate income or profit in that market. The competitors of these predatory firms may be seriously injured and some may be forced out of business, thus impairing the competitive structure of the market and leading toward monopoly.

The authority given milk control agencies to grant and revoke licenses might be used to restrain destructive price-cutting and other predatory practices, but the laws do not give sufficiently clear instructions on this point.

Convenience and necessity (3). The New York Milk Control Law goes further than other similar laws in authorizing its administrative officer to refuse to grant a new license, or to extend the scope of a license previously granted, if he finds that the market is already adequately served.

This is comparable to the practice in public utility regulation where it has been customary to strictly limit competitive duplication of facilities and service. This policy in dealing with recognized public utilities is predicated on the belief that the extra cost of maintaining duplicate systems would exceed the value of any gains in efficiency or service likely to be obtained through more competition. Whether the same assumption is justified in the case of milk distribution is open to doubt. Restrictive licensing excludes most innovators and thereby tends to prevent or delay the introduction of new methods and improved practices.

At the same time, restrictive licensing without control of dealers' margins, profits, or services seems likely to create a situation in which the benefits of limiting the number of competitors in a market will go mainly to the privileged dealers rather than to consumers or producers.

What of the Future?

We must anticipate a continuation of major trends that have been pointed out in this review. The market for milk will continue to expand with the steady growth of population. Probably there will be a further shift toward skimmilk or low-fat milk. In spite of previous failures, some effort to capture a part of the fluid milk market with an acceptable lower-priced substitute may succeed. This will be

more likely to happen if prices of fluid milk are maintained at an unduly high premium over manufacturing milk.

Labor costs will continue to rise, and milk distributors will make further changes in their operations in response to this pressure. Still more labor-saving equipment will be installed. There will be further plant consolidation. More of the remaining milk dealers will limit their activity to certain types of operation, such as processing. It remains to be seen whether the labor unions will be able to bring subdealers under their control. If they do not succeed in this, the delivery end of the milk business is likely to pass more and more into the hands of these self-employed distributors.

Store distribution will continue to increase at the expense of home delivery, especially where retail distributors fail to price their milk in accordance with the cost of efficient service to customers who take several quarts per delivery.

More milk will be sold through vending machines, but they will not become a major competitor of retail routes or stores.

The pricing and distribution of milk will be subjected to more regulation rather than less as time goes on. This is practically inevitable with more and more of the business coming into the hands of large companies and with a steady decline in the number and influence of small operators. Moreover, each new type of regulation calls for another. A good example is restrictive licensing of milk dealers, which will hasten the day when regulation of margins, profits, and services is found to be necessary. Another is the fixing of minimum producer prices at higher levels than necessary to obtain an adequate supply. It will be surprising if this practice does not lead to the assignment of quotas, allocating to producers their respective shares in the market for fluid milk.

Some of these indicated future developments may not be to our liking. It may be possible to delay or to prevent some of them, but the main task of the industry will be to adjust policies and operations promptly as conditions change.

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Governmental Control of the Dairy Industry Other Than Health Measures and Standards

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Milk price-control legislation came into being primarily as the result of disastrously low farm prices in the early 1930's. Dairy farmers were particularly hard-hit by the depression. With a perishable product they had little or no protection in the market place. Collective bargaining between producers and distributors broke down in most markets. Financial losses of producers led to violence, dumping of milk, and general disruption of the dairy industry.

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In this situation it was evident that something had to be done to raise the income of milk producers and restore some measure of stability to the milk market. Between 1933 and 1940, 26 states enacted legislation to control minmum prices to be paid producers as well as those to be paid by consumers. Early in 1933, the United States Agricultural Adjustment Act, which permitted the establishment of minimum wholesale and retail milk prices, became a law. In 1933, nine states, including New York, Connecticut, Florida, Pennsylvania, Ohio, Oregon, New Jersey, Vermont, and Wisconsin, enacted legislation to control both producer and consumer prices for milk. In 1934, Massachusetts, Rhode Island, and Virginia enacted similar legislation, followed by Alabama, Indiana, Maine, Montana, and New Hampshire in 1955. In January, 1934, the federal government abandoned the fixing of resale prices. By 1956, producer prices were regulated in 65 federal order markets, which cover over half of the urban population of the United States.

In 1937, Georgia, California, and Utah passed complete milk price-fixing laws. Between 1938 and 1940, Delaware, Maryland, Michigan, South Dakota, Texas, and Washington enacted laws controlling both producer and resale prices, thus rounding out the 26 states which at one time or another were attempting to control milk prices.

In addition to federal and state regulation of milk prices, in recent years the federal government has set floor prices on butter, cheese, and nonfat solids. Analysis of each of the three main types of governmental price regulation is included in this discussion.

Do Federal Milk Orders Act as Barriers to Milk Consumption?

One of the basic functions of a federal milk order is to encourage the production of milk adequate to supply the needs of a market. Since supplies usually are directly related to milk prices, probably the most important function of the federal government is to determine what prices will insure an adequate supply without burdening the market with excessive reserves.

Total milk receipts at 15 to 20% above the volume needed to meet whole milk needs in the shortage month are necessary in order to provide for day-to-day fluctuations in production and sales. The question of how much reserve milk is needed from approved sources both to supply day-to-day variations and to insure an adequate supply of milk for the long run is one of judgment. For the purposes of this discussion it is assumed that a 35% reserve above the volume of approved milk needed in the least-surplus month, or double the reserve needed for day-to-day changes, would be sufficient to furnish an adequate supply of milk to meet market needs both in the short run and in the long run. In some markets a reserve far less than 35% would be ample to supply all market needs in the shortage month.

The question can then be asked, do any federal order markets have Class I prices which appear to be higher than necessary to insure an adequate supply of milk? To answer this question two sets of data were obtained. The first set showed the proportion that milk receipts in each of 48 federal order markets exceeded the amount needed for October and November 1952, 1953, and 1954 (Table 1). For the purpose of this analysis, markets were divided into groups, those with over 500,000 population, and those with 500,000 or less *(1)*. The second set of data showed a comparison of changes in Class I prices in the larger federal order markets with those in Chicago and Minneapolis–St. Paul from 1929 to 1954. Each set of data is reviewed and an analysis made of relationships.

Analysis of Class I Pricing Under Federal Orders

A study of 48 markets reveals the following facts:

1. Of these markets 27 had milk reserves in what usually are shortage months that were reasonably in line with sales (Table 1). An upward trend in milk reserves in some of these markets indicated the possibility of excessive reserves in future years if growth in output continues.

2. Thirteen markets had milk reserves below those needed to insure an adequate supply of milk.

3. Eight markets had milk reserves larger than appeared to be necessary to insure an adequate supply of milk in the shortage months.

TABLE 1

Milk receipts as percentages of milk used in fluid forms, 48 Federal Order Markets, 1952, 1953 and 1954[a]

Markets of over 500,000 population	Type of pool[b]	October			November		
		1954	1953	1952	1954	1953	1952
Puget Sound (Seattle)	M	159	138	114	145	142	118
Boston	M	153	159	151	137	157	144
New York	M	148	162	141	143	139	135
Cleveland	M	137	130	133	139	134	131
Detroit	M	134	128	125	132	134	128
Chicago	M	131	135	120	135	155	131
New Orleans	H	130	116	109	133	123	113
Louisville	M	125	110	109	126	119	112
Kansas City	M	124	121	111	134	139	117
Philadelphia	H	124	112	116	123	117	114
Cincinnati	M	110	101	112	112	109	109
Milwaukee	H	108	107	102	106	118	108
Minneapolis–St. Paul	H	107	118	111	114	138	128
North Texas (Dallas)	M	106	106	96	105	115	103
St. Louis	M	99	93	82	103	103	88
San Antonio	M	80	90	79	78	95	79
Markets of 500,000 or under							
Duluth-Superior	M	165	157	150	170	163	142
Fort Wayne	M	153	128	143	139	132	134
Quad Cities	M	137	133	108	138	142	115
Cedar Rapids–Iowa City	M	136	128	110	141	142	116
Lima	H	133	122	97	—	134	104
Wichita	M	132	127	120	133	154	132
Dubuque	M	129	133	122	140	156	138
Neosho Valley	M	129	130	114	143	152	121
Muskegon	M	125	120	—	119	129	—
South Bend–LaPorte	M	124	111	98	118	116	100
Stark County	M	122	114	—	120	122	—
Dayton-Springfield	M	121	109	117	118	119	115
Oklahoma	M	119	120	99	119	131	110
Tulsa-Muskogee	M	118	118	101	119	132	107
Columbus	M	114	108	107	107	120	112
Nashville	M	112	100	106	121	112	110
Sioux City	M	112	115	99	112	128	108
Springfield	M	112	106	107	106	111	106
Topeka	M	113	106	97	128	128	111
Omaha	M	111	110	87	114	121	94
Tri-State	H	103	89	87	95	93	88
Merrimack Valley	M	100	98	99	95	101	96
Paducah	M	101	73	72	99	77	66
Rockford-Freeport	M	101	110	105	101	116	115
Fort Smith	M	99	112	101	96	124	105
Sioux Falls–Mitchell	M	99	105	87	95	108	99
Memphis	H	97	93	97	98	103	102
Toledo	H	97	94	83	102	104	89
Knoxville	M	94	98	99	90	104	97
Worcester	M	89	86	91	85	89	91
Fall River	H	82	93	97	74	95	95
Central Texas	M	81	96	—	82	95	—

[a] Adapted from USDA Marketing Research Report No. 98, June 1955, Table 18, p. 47.
[b] M = market-wide pool. H = individual-handler pool.

The four markets with a population over 500,000 that appeared to have excessive reserves in shortage months were Puget Sound (Seattle), Boston,[1] New York, and Cleveland. In each of these federal order markets Class I prices have been materially higher in recent years than in Chicago and Minneapolis–St. Paul, where Class I prices have been kept in line with the national level of prices of manufactured milk. The four markets with a population under 500,000 that appeared to have excessive reserves in shortage months were Duluth-Superior, Fort Wayne, Quad Cities, and Cedar Rapids–Iowa City.

Looked at in over-all perspective, the fact that 40 out of 48 federal order markets did not have excessive milk reserves in the shortage months in 1954 indicates that Class I pricing under the present operation of federal orders, for the most part, has been reasonable and in line with public interest. This, combined with the fact that milk orders have been very helpful in stabilizing markets where they operate, indicates the desirability of keeping the federal order program as a permanent part of the structure for pricing milk to producers. On the other hand, the fact that eight of the 48 federal order markets had milk reserves higher than appeared to be necessary indicates that Class I prices in these markets have been held at a level higher than necessary to insure an adequate supply of milk.

Leaders of farmer organizations in some areas have believed that a high Class I price is always associated with a higher income to their members. This assumption is not necessarily true. The loss of 18% in per capita consumption of milk in the New York market between 1945 and 1954 forced additional milk into lower-price uses. This, in turn, not only lowered the blend price to producers but encouraged New York consumers to turn to lower priced dairy products or to milk substitutes.

Furthermore, the loss of a Class I market is a serious threat to the long-run stability of the dairy industry. It is indeed fortunate for dairymen as a whole that Class I prices in most federal order markets have been kept in line with competitive prices. This is one reason why per capita milk sales in the United States in 1954 were 13% above those for 1940, rather than being limited to the 5% increase shown for New York.

[1] In a letter dated February 9, 1956, Mr. Herbert Forest, Director Dairy Section, A.M.S., USDA, pointed out that a market such as Boston must be able to supply the fluid milk needs of secondary markets such as Fall River, Merrimack Valley, Springfield, and Worcester, whose milk receipts compared with fluid needs were low as compared with those of Boston (Table 1). Assuming this to be a valid assumption, the fact still remains that in 1954 milk receipts in Boston in the lowest month in 1954 were over 35% above the amount of milk actually used for fluid needs for Boston plus sales outside the marketing area.

Do Federal Orders Operate as Barriers in Ways Other than Class I Pricing of Milk?

Two other ways in which one or more federal orders have acted as barriers to increased consumption of milk or cream are: (1) the inclusion of concentrated milk as a Class I product within the market where it is sold and (2) an unduly high price for cream.

During the spring and summer of 1951 there was a large upsurge in the sales of fresh concentrated milk. This milk was concentrated on a basis of 3 to 1 and could be reconstituted without any loss in flavor. In some markets this product sold as much as three cents a quart below the price of regular milk. Milk producers in areas having a high Class I price, as well as some distributors, became alarmed at the possibility of the new product replacing fresh milk since it could be transported at one-third the cost of fresh milk. In such areas interested groups immediately turned to the federal milk order and had concentrated milk included as a Class I product in the area where it was sold. This action forced distributors to pay the Class I price for the new product and thereby eliminated part, if not all, of the potential saving to consumers.

The experience in the Boston market illustrates the way in which the federal order acted as a barrier. After an intensive advertising campaign in March and April, 1951, sales of concentrated milk in this market increased to about 200,000 qt., or 2% of total milk sales. At this time consumers could buy concentrated milk for about three cents a quart less than fresh milk.

Sensing the danger to their Class I price, which was then (1951) at a high level, the milk producers in the Boston market called for a hearing, after which concentrated milk was incorporated in the definition of Class I milk. Concentrated milk was also included as Class I item in several other federal order markets during the early 1950's and has continued in that classification up to the present time (1956).

What effect did including concentrated milk as Class I have upon sales of this product? The situation in Boston helps to answer this question. The principal reason why people bought concentrated milk in Boston and other markets in 1951 was to make a saving. Consumers cannot be expected to do something for nothing. Since inclusion of concentrated milk in the high-price Class I bracket in Boston took away most of the price advantage, sales dropped off, and by the end of 1951 concentrated milk was eliminated from the market.

The Boston situation stands out in sharp contrast with that in San Francisco, where concentrated milk has been sold at 3 cents a quart below the price of regular milk since June, 1951, and present sales (1956) are around 25% of those of regular milk in the stores where it is sold.

Inclusion of concentrated milk as a Class I product under federal orders was one factor which resulted in the discontinuance of sales of this product in Boston and other markets in 1951. At the same time distributors, alarmed about the effect that increased sales of concentrated milk might have on their capital investments, took steps to curb the sales of this product. This was another factor that resulted in the elimination of concentrated milk in some markets during 1951.

Do Federal Orders Affect Cream Prices?

Since the inception of federal milk orders it has been the policy of the U. S. Department of Agriculture to accept the quality standards of milk in each locality and to apply prices to milk conforming to these standards. The reasoning is that the setting of quality standards is not properly the function of the federal government and is not authorized by the Agricultural Marketing Agreement Act. The author agrees with this reasoning as a practical basis of operation. Some question, however, may be raised as to the soundness of accepting such standards in its price-making function when it results in establishing a price materially higher than would exist under competition.

Specifically, during the past two decades, cream prices in New York have been materially higher than those of Boston and Philadelphia. Between 1937 and 1955, New York cream prices averaged over $5.00 per 10 gal. higher than in Philadelphia and Boston. Cream is regularly imported from midwestern producing areas in both the Boston and Philadelphia markets. In contrast, the New York market has limited its area of inspection, and shipment of midwestern cream for table use is not permitted on this market. This has resulted in a higher cream price than would exist under competition. Since the New York federal order Class II price is closely related to the New York price for 40% cream, in essence the federal order supports the barrier created on cream by inspection requirements and tends to negate the law of comparative advantage for the New York market insofar as cream is concerned.

Between 1940 and 1954 per capita consumption of cream in the New York market declined 35%, not quite double the reduction (20%) for the United States during the same period. Is it not reasonable to believe that the greater decrease in cream consumption in the New York market during this period was associated with the higher wholesale price on the product?

How Should Markets that Use Federal Orders as Barriers Be Handled?

With age each group in our economy tends to get "hardening of the arteries" and tries to prevent any changes which would disrupt the "vested interests." Federal milk orders have been in operation since 1934. Although in most markets Class I prices under them appear to be reasonable, in eight areas they are exhibiting definite signs of old age through the use of governmental power to establish prices for milk materially higher than would exist under competition. Left unchecked, this tendency could wreck the use of federal orders in all areas.

The main supporters of federal orders since their inception have been one or more milk producers associations in each marketing area. Unduly high prices for milk in some marketing areas are probably the result of political pressures applied by these associations on governmental employees administering them. It should be clearly understood that this type of milk pricing is not limited to the federal government. Similar unduly high prices have been tried by some state governments and by some milk-producer organizations in markets not under federal controls. However, fixing of unduly high prices for milk by either federal or state authority is more pernicious than when such prices are the result of negotiation between milk producers and milk distributors, since such exactions appear to give legal approval to what otherwise has been an illegal practice. Specifically, the producers' association in Chicago, along with the milk dealers, was indicted in 1938 by the Anti-Trust Division of the U. S. Department of Justice for conspiracy in restraint of trade, and these indictments were upheld by the U. S. Supreme Court in 1939. Although there may be some question as to whether or not federal milk orders are subject to the Sherman Act, a careful reading of the Agricultural Marketing Agreement Act of 1937 makes it clear that it is not the purpose of the Act to establish prices that are unduly high nor to restrict the interstate flow of milk.

In analyzing the problem and attempting to find remedies to prevent fixing of unduly high prices by government decree, it is necessary: *(a)* to examine facts as to whether prices established by federal orders are in the public interest and *(b)* to suggest remedies which will remove political pressures so that minimum prices established for producers will be in the public interest.

Probably the best single way to correct the situation is to present the facts at frequent intervals to those who are charged with the responsibility of legislation under which federal orders operate. If the authority granted is used to establish Class I prices that are unduly high and that curb increases in per capita sales of milk, legislative action can be invoked to restore federal order pricing so that prices will be in line with public welfare. Also, corrective legislation can be invoked if necessary to prevent the use of federal orders to curb the intermarket shipment of concentrated milk or cream when prices established for these products are materially above their competitive value.

State Control of Consumer Prices

Milk prices, like those of corn, cotton, hogs, or any other farm commodity, cannot be kept above their competitive level without discouraging sales and encouraging burdensome surpluses. Many economists agree that a floor should be placed under producer prices, but they also agree that from a long-run viewpoint the floor should not be so high as to prevent the flow of commodities to the commercial market.

State control of consumer prices is not necessary to protect the public health. Municipal, county, and state regulations can adequately control the quality of milk. Neither do federal milk orders presume to tell a local marketing area how to control the quality of milk. Rather, the order sets forth the prices that shall be paid for milk of a specified quality.

Does state control tend to exact consumer milk prices which are higher than would exist under competition? A comparison of market milk prices with those of evaporated milk from 1919 to 1954 (Table 2) has shown that:

1. For 50 cities the market milk price in 1919 averaged about one-half cent per quart lower than the evaporated milk price; in 1954, the market milk price was 6¼ cents higher than the evaporated price.

2. In the South, the market milk price in 1954 averaged 8.9 cents a quart higher than the evaporated price; in the Northeast, 7.8 cents higher; in the West, 5.3 cents higher; and in the Midwest, 2.5 cents higher.

Another breakdown of market milk prices and evaporated milk prices in these same cities showed that:

1. The market milk price in 1954 for the 18 cities under state control averaged 8.35 cents per quart higher than the evaporated price and 7.89 cents above that for 1919.

2. The market milk price in 1954 for the 32 cities not under state control averaged 5.1 cents above the evaporated milk price and 6.25 cents above that for 1919.

The South and the Northeast are located in the so-called "deficit" areas of production and, historically, retail prices in these areas have been higher than in the Midwest or Far West. On the other hand, eight of the ten states still having state control of consumer prices are located in the South or Northeast. These states are Alabama, Georgia, New Hampshire, Maine, Pennsylvania, Rhode Island, Virgina, and Vermont. California and Montana are the only two states outside of these areas that still control consumer prices. State control of consumer milk prices in Florida has been temporarily suspended.

Increases in market milk prices relative to evaporated prices during the past 35 years have resulted from additional costs to meet quality requirements, growth in population, higher consumer incomes, higher per capita consumption, and monopoly price exactions of one sort or another. Insofar as the facts shown for the 50 cities are representative of markets as a whole, they would seem to indicate that state control had resulted in exaction of consumer milk prices somewhat higher than would have existed under competition. To the degree that this has been true, state control of consumer prices has been against the public interest since high prices tend to curb sales of milk.

Does State Price Control Eliminate Unfair Trade Practices?

This question was one covered by the National Grange and reported in their study of "Barriers to Increased Consumption of Fluid Milk." Excerpts from this study follow:

> "How can one dealer compete effectively with another for milk business when he is prohibited by law from using the most important of all competitive forces—price?

TABLE 2

Prices paid by consumers for whole milk and evaporated milk, specific cities and the United States by regions, 1954, 1949, 1939, 1929, and 1919

Market	Market milk	Evaporated milk	Net amount which price of fresh milk exceeded per qt. of the milk equivalent evaporated milk				
	Store price[a]	Price per qt. of milk equivalent[b]					
	1954		1954	1949	1939	1929	1919
South	23.75	14.88	8.87	7.96	5.09	3.57	1.69
Northeast	22.97	15.01	7.78	6.43	4.45	3.35	–1.02
West	20.42	15.11	5.31	4.92	2.91	2.00	–1.66
Midwest	17.69	15.22	2.47	3.04	2.56	1.44	–2.07
United States[c]	21.32	15.04	6.27	5.73	3.90	2.69	–0.54

[a] Source: USDA, *Fluid Milk and Cream Reports* and USDL, *Labor Statistics, Retail Food Prices by Cities.*

[b] 1 can of evaporated milk = 14½ oz. Concentrated 2.2:1 (2.2 × 12½ oz. = 31.9 oz.) 1 qt. of milk = 2.15 lb.; 2.15 × 16 oz. = 34.4 oz. 34.4 ÷ 31.9 =1.07836. Multiply this factor by the retail price of evaporated to find what a quart of milk would cost purchased at the evaporated price.

[c] Average of 50 cities.

The alternatives available to him are few and not particularly promising. He might, for example, try to increase services in some legal way. But opportunities for increased services, of a kind that would pay off in greater sales, are exceedingly limited. Moreover, they tend to be costly . . .

"If these possible avenues of competition then offer but scanty promise, in what direction can the dealer turn? The answer is that he can, and frequently does, resort to illegal trade practices. Resale price control officials admit privately that they are virtually powerless to halt these demoralizing practices . . . The total number of individuals, locations, and opportunities available for infractions of the law is so great that adequate policing is well-nigh impossible. State staffs engaged in such work are so limited in size that no more than token enforcement can be attempted.

"Under the circumstances, it is impossible to know just how widespread this particular form of violation has become. There is no disposition here, and certainly no reason, to indicate that all or any majority of milk distributors in controlled-price states are lawbreakers. But the temptation exists, in the absence of other effective and legal forms of competition, to engage in illegal transactions. The temptation is compounded, of course, in markets where the practice has been more or less uniformly accepted and condoned. Where there is a common sanction of such trade practices, a form of standard undercover price competition has developed. Obviously, however, the benefits do not accrue to the customer.

"Unconfirmed reports and allegations about violations were freely offered by many in the industry. The introduction of these accounts, as a matter of fact, assumed a pattern, beginning with: 'Don't use my name, but let me tell you . . .' The allegations usually referred to discounts, rebates, tie-in sales, loans, gifts, and the provision of extra services or equipment such as refrigerators, signs, and display counters. In one instance, a dairy was said to operate a loan service for selected customers—making available sums up to $1,000 at no interest and without security pledge or terminal date.

"Enforcement officers, of course, are able to track down a certain number of violators, obtain witnesses, and win court convictions. The disposition of such cases is a matter of public record. Perhaps the most unfortunate aspect of this situation is that dealers and distributors who are otherwise law-abiding in all respects feel forced to adopt illegal tactics in order to sell milk."

From the above evidence it is clear that state price control does not eliminate unfair trade practices.

Does State Consumer Price Control Promote Orderly Marketing?

The path of governmental fixing of consumer prices of milk has been strewn with trials and tribulations. At one time or another 26 states and the federal government have had laws fixing resale prices of milk. Together these states have a population (1950) of 113,000,000, or three-fourths of our entire population. Fifteen of the 26 states and the federal government have abandoned resale price control, and in Florida this type of control has been suspended. In examining the situation one might well say that state resale price control has encouraged disorderly rather than orderly marketing. Furthermore, reports from some of the states where resale price control still exists indicate that the disorder characteristic during their early years of operation still exists.

History of the Discontinuance of State Control of Resale Milk Prices

Consumer price control in the several states disappeared by various stages. By January, 1934, the federal government abandoned fixing of retail prices and since that time has centered its major attention upon regulation of prices to be paid producers. By the end of 1940, state milk price-fixing laws had been repealed or allowed to lapse in eight states, including Delaware, Maryland, Michigan, Ohio, South Dakota, Texas, Utah, and Washington, and in 1937 New York had repealed the resale price provisions of its law.

Since 1940, seven other states, including Connecticut, Indiana, Masachusetts, New Jersey, Oregon, and Wisconsin, have discontinued state control of resale milk prices. In the fall of 1955, at the request of the governor, state control of milk prices in Florida was discontinued for one year.

Does State Resale Price Control Promote Economy and Efficiency?

One of the stated purposes of milk price control was to promote economy and efficiency. The question which needs an answer is: Does or does not state resale price control bring about these desirable results? Analysis of distributor's margins in 24 cities indicates that three of the four state-controlled cities were less efficient in 1954 than in 1929. Consumer prices in Philadelphia and Pittsburgh have been under state control since 1934 and those in Los Angeles and San Francisco since 1938. In 1929, Pittsburgh ranked ninth from the top in size of gross distributor margins. In 1954, only two out of the 24 markets had margins wider

than those of Pittsburgh. As in Pittsburgh, margins in Philadelphia have increased greatly since 1929. In 1929, Philadelphia ranked 14th in 24 cities. By 1954, only seven markets had gross margins wider than those of Philadelphia. Margins in San Francisco also have widened in recent years. In 1929, San Francisco ranked 17th in 24 cities. By 1954, only nine of the 24 markets were less efficient than San Francisco.

In contrast to the changing picture in Pittsburgh, Philadelphia, and San Francisco, milk distribution in Los Angeles, measured by margins, was more efficient in 1954 than in 1929. In 1929, only one market had a margin wider than Los Angeles, but by 1954, 13 markets were less efficient than this city.

With such a limited sample it is impossible to make broad generalizations. State resale price control in Pennsylvania, however, has undoubtedly discouraged the use of new methods and new technology. The situation in California is less definite. A relatively higher margin in San Francisco indicates that state control has not promoted economy and efficiency. In contrast, it would appear that definite progress had been made in improving economy and efficiency in Los Angeles.

Although its relative position improved between 1929 and 1954, Los Angeles was still less efficient than 11 other markets and had a unit margin of 2.5 cents a quart wider than the margin in Washington, D. C. With the continuance of present controls in California against new technology and the insistence that costs cannot be reduced, it is doubtful that margins in Los Angeles will be reduced to anywhere near the level of those in Washington. In fact, for many years one large group of chains in the market have tried to get margins reduced as much as two cents a quart below the present level. Unit costs of this chain would permit lower unit costs and still have a profit. No heed has been given to this request by the State Control Bureau. Hence, the conclusion that one must reach, even for Los Angeles, is that state resale price control does not promote the ultimate in economy and distribution costs.

Does Insurance of a "Reasonable Return" Encourage Efficiency?

Faced with the difficulties of fixing margins on the basis of actual costs, some states have turned to average over-all costs, including profits, as a basis for determining prices to be paid by consumers. Such costs are based on the operating statements and balance sheets of the distributors in the market. The authorization of this method and its use under the Pennsylvania Milk Control Law illustrate how this method operates.

The authority for determining milk prices in Pennsylvania is set forth in their Milk Control Law as follows:

> "The commission shall base all prices upon all conditions affecting the milk industry in each marketing area, including the amount necessary to yield . . . a reasonable return to the milk dealer or handler. In ascertaining such returns, the commission shall utilize a cross-section representative of the average or normally efficient . . . dealers or handlers in the area."

With the above authorization, each year the Pennsylvania Milk Control Commission requires each distributor to submit a balance sheet and an operating statement. These statements are consolidated and then made available to everyone in the market.

The use of average costs, wholesale and retail, of all distributors in a market such as Pittsburgh gives as much weight to the least-efficient as to the most-efficient distributor, whose unit costs are much lower. Hence, the use of average costs by a milk-control agency in fixing resale prices is economically unsound and results in the deliberate encouragement of inefficiency in distribution. This helps to explain why the relative efficiency of distribution in both Pittsburgh and Philadelphia has declined since 1929. Also such a method of computing costs provides no basis for establishing the many different prices (235 in Pittsburgh) which are set by the Control Board.

Should Milk Control Agencies Legalize Inefficiency?

The regulation of public utilities by law is based on the protection of the consumer from unjust or exorbitant rates, but it is also predicated upon allowing the utility a fair profit on its investment and operation of its plant. A milk dealer falls into the same category when the state controls consumer prices. If margins are lowered in line with the most efficient group of distributors, a dealer can allege "confiscation" and appeal to the "due process" provision of the constitution. This tends to limit the usefulness of governmental price control in obtaining increased efficiency.

Should one accept the theory that every dealer, efficient or inefficient, should be permitted to make a fair profit? If so, where would this theory lead to over a period of years? If the automobile industry had adopted that theory back in 1900, would automobiles have come into common use, with one car for every four people, or would they still be a luxury with one car per 1,000 or more people, as exists in most of Europe?

Governmental Price-Supporting Programs

As previously indicated, Congress in 1933 passed the Agricultural Adjustment Act to support farm prices above the disastrously low level to which they had fallen. As part of this program the government put in price supports for dairy products. Price supports were made

effective by purchasing products on the open market. Between 1933 and 1941, when this program was operating, governmental purchases ranged between 0.08% of the total milk production in 1936 and 2.8% in 1938.

Between 1942 and 1948, the commercial market absorbed all the milk and manufactured dairy products produced. With the recession of 1949, consumer income fell off, and an act was passed to support the prices of butter, cheese, and nonfat solids at 90% of parity. In 1949, 2.2% and in 1950, 3.1% of the milk produced was purchased by the government. As a result of the Korean War, there were no governmental purchases of dairy products in 1951 and only 0.3% of the total milk production in 1952.

In 1953, milk production was about six billion pounds higher than in 1952. This huge increase combined with the cessation of the Korean War flooded the market. In 1953, the government purchased 8.2% of the total production of milk.

On April 1, 1954, support prices of butter, cheese, and nonfat solids were reduced from 90 to 75% of parity. Butter consumption in the United States in 1955 increased to 9.2 lb. per person as contrasted to 8.6 lb. in 1952. In 1955, governmental purchases of dairy products fell off to less than half those of 1953 (3.7%). An upward trend in butter and cheese purchases is indicated for 1956.

Although they are confronted with a cost-price squeeze, the present situation (1956) is not critical for dairy farmers. In the first place, consumer income in the United States is at a very high level. In 1954 this averaged $1,770 per person, or over three times that for 1935-39 ($532). When corrected for changes in purchasing power, American consumers in 1954 had $1.67 for each dollar in the prewar years. In the second place, butter is no longer as dominant a price-making force as formerly. In 1955, only 25% of the milk produced in the country was manufactured into butter, as compared with 41% in 1939. In the third place, many dairy farmers have lowered unit production costs through improved breeding, feeding, and management practices. Finally, increases in population combined with higher per capita sales will require more than two billion additional pounds of milk each year to supply the nation's needs. The dairy industry is a going concern and likely to be one for a long time.

The Nature of the Dairy Enterprise

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The past half-century has been the Golden Era of the dairy industry. Dairying is so big that the amount of money involved, the number of people who depend upon it for a living, and the extent of the service that it gives are hard to comprehend. Dairying has truly become a business giant that exerts a great influence upon the economic, nutritional, and political welfare of people all over the world.

J. J. Sheuring

The dairy industry of the United States sells more than five billion dollars worth of products annually *(9)*. This involves more than 8,000 dairy plants, employing approximately 225,000 people, who are paid more than $300,000,000 annually in salaries *(9)*. Dairy plants spend more than four billion dollars each year for milk, materials, fuel, electricity, equipment, and supplies *(9)*. At least 6,500 equipment manufacturers and jobbers sell more than $450,000,000 worth of their products to the dairy industry each year *(3)*. More than 200,000 trucks are needed to move milk from the farm to the plant and thence to the consumer *(2)*.

The dairy enterprise includes the production, procurement, processing, storage, and distribution of butter, cheese, concentrated milk products, ice cream, ices, sherbets, plastic cream, and other special products derived from milk. Some dairies also distribute eggs, candy, salad dressing, margarine, and other food products not directly related to milk.

Changes in the Size of the Dairy Industry

The collection of data on the production of manufactured dairy products was started under the provisions of the War Emergency Act of 1917. With the expiration of the act in 1920, the U. S. Department of Agriculture had no authority to require manufacturers of dairy products to report any statistical information *(8)*. Some of the state legislatures, in the early 1920's, authorized certain agencies to collect and publish data concerning the production of manufactured dairy products within those states. In 1925, the Bureau of Agricultural Economics of the USDA began cooperative agreements with some of those state agencies to report their market information to Washington. In the late 1940's, the staff of the Dairy Statistics Branch of the USDA set up a project to procure the production data by states of butter, ice cream, and all cheese except cottage, pot, and bakers'. The corrected data, concerning the production of manufactured dairy products from 1916 through 1939, were published by the Agricultural Marketing Service of the USDA in 1953 *(8)*. Data concerning production and consumption and other pertinent information relating to the dairy industry are now published regularly by the Agricultural Marketing Service, USDA. Labor statistics and data concerning the business aspects of the dairy industry are compiled and published by the United States Department of Commerce.

It would be impractical to present in this paper complete statistical data concerning the dairy industry for the past 50 years. However, a brief summarization of some of the data is probably of some value in showing how rapidly dairying has progressed.

The number of milk cows on farms increased from 17,832,000 in 1905 *(5)* to more than 24,000,000 on 602,000 dairy farms in 1955 with a livestock valuation exceeding $3,250,000,000 *(6)*. The production of milk increased at the same time from 64 billion *(5)* to more than 123 billion pounds annually with a cash value exceeding four billion dollars *(6)*.

Approximately 37.7% of the milk produced in 1954 was used for fluid milk consumption in cities and villages. Of the remainder, 8.5% was consumed on farms, 23.2% was used in churning of creamery butter, 3.4% in making farm butter, 10.9% for the manufacture of cheese, 5.0% in evaporated and condensed milk products, 6.3% in ice cream and frozen dairy foods, 2.7% for calf feed, 0.6% for dry whole milk and 1.7% in miscellaneous food items *(2)*.

The more than five billion dollars paid for dairy products were divided as follows: 56.95% for material costs, 22.16% as salaries and wages, 5.53% for plant delivery and office supply expenses, 5.52% for containers, bottles, cans, etc., 5.52% for insurance, depreciation, and similar expenses; taxes and licenses took 3.06%, advertising used 1.07%, and the net operating profit accounted for 2.28% *(2)*.

Developments in the butter industry. Creamery butter production, from 2,000 creameries in 1954, was 1,448,688,000 lb. *(6)*. In 1904, there were 5,235 creameries that manufactured less than 800,000,000 lb. of butter *(9)*. The peak production year was 1933 when 1,795,000,000 lb. of butter were produced *(8)*. Since that time, the production of creamery butter steadily declined until only 1,171,339,000 lb. were churned in 1946 *(8)*. A slight increase in production has occurred since World War II with 1,448,688,000 lb. being churned in 1954 *(6)*. The per capita consumption of butter continued to decrease from a peak of 18.3 lb.

in 1934 to a low of 8.6 in 1953. A slight increase in per capita consumption of butter was expected for 1955 *(2)*.

The per capita consumption of margarine increased steadily from 1.2 lb. in 1909 to more than 8.0 lb. in 1955. There was an increase in total production during the same time from 113,000,000 to more than 1,300,000,000 lb. of margarine annually *(5)*.

Some major changes have occurred in the butter industry. Early butter plants were small and were located near the source of cream supply. For example, there were 5,235 creameries in 1904 employing 12,547 people. In 1947, there were 2,157 creameries employing 37,988 people *(9)*. Those figures indicate that a definite trend has occurred towards fewer creameries, more employees, and greater production per unit.

Developments in the cheese industry. The cheese industry has truly come of age during the Golden Era. The total annual production of cheese, exclusive of full-skim, American, cottage, pot and bakers', has increased from 479,390,000 in 1919 to 1,022,480,000 lb. in 1954 *(8)*. The per capita consumption of American cheese increased steadily from 2.4 lb. in 1909 to 7.7 lb. in 1954 *(2)*. There have also been significant increases in consumption of Swiss, Brick, Münster, Neufchatel, cream, Blue, and Italian varieties of cheese. The consumption of cottage cheese has been phenomenal. In 1925, only 60,000,000 lb. of cottage cheese were produced *(1)*. By 1954, the production had increased to more than 500,000,000 lb. annually *(7)*.

Cheese making was primarily a small unit operation during the first 30 years of the century. The factory usually was located close to the supply of milk. In some sections of northern Illinois and Wisconsin, cheese plants were located every two or three miles, and milk was delivered to the plant daily. Cheese making was an art handed down from generation to generation in a family. The cheese factory was an important factor in the welfare of the community. Owing to difficulties of marketing and as the result of the building of better roads and equipment, the small cheese plants began to disappear in the late 1920's and early 1930's. In 1904, there were 3,610 cheese plants in the United States employing 2,829 people; in 1923, there were 3,400 plants employing 4,100 people; in 1947, only 1,811 plants employed 16,579 people and sold $500 million more cheese than the 1909 factories *(9)*.

Developments in the ice cream and frozen dairy products industry. The number of ice cream plants in the United States has not changed materially in the last 50 years. There were 2,437 ice cream manufacturers in 1914 and 2,273 in 1947. The number of employees in 1947 was 80,000, compared to 12,000 in 1914 *(9)*. However, ice cream production increased from 142,912,000 gal. in 1918 *(8)* to 596,000,000 gal. in 1954 *(7)*. The peak production was 713,000,000 gal. in 1946 *(7)*. The per capita consumption of ice cream increased from 0.9 gal. in 1916 to a peak of 5.0 gal. in 1946. The average per capita consumption of ice cream since 1946 has been approximately 3.7 gal. *(2)*.

The production of ice milk has increased steadily to a total of 78,742,000 gal. in 1954 *(7)*. Vegetable fat frozen desserts were introduced in the early 1950's and the production reached 34,048,000 gal. in 1954 *(7)*. More than 80,000,000 gal. of soft-serve were sold in the same year *(4)*.

Developments in the condensed and dried milk industry. The manufacture of evaporated milk, unsweetened, and skimmed condensed accounted for a production of 1,194,496,000 lb. in 1919 *(8)*. There was a steady increase in volume to a peak of 3,776,383,000 lb. in 1935 *(8)*. Since that time a steady decrease in volume has occurred to approximately 2,500,000,000 lb. in 1954 *(8)*. The per capita consumption of condensed dairy products has also decreased to some extent. The per capita consumption of evaporated milk reached a peak of 18.1 lb. in 1948 and dropped to 14.6 lb. in 1954 *(2)*.

The production of nonfat dried milk solids has showed a steady increase in volume since 1935, from 187,530,000 lb. *(8)* to 1,402,374,000 lb. in 1953 *(5)*. Several new plants started producing nonfat dry milk solids in 1954 primarily by the spray process. During the past decade, there has been a rapid change in the proportion of nonfat dry milk solids manufactured by the spray process. In 1945, 46% of this product was manufactured by the spray method; the proportion had risen to 83% in 1954. The per capita consumption had increased from 0.2 lb. in 1920 to 4.6 lb. in 1954 *(5)*.

Changes in the fluid milk and cream industry. This segment of the dairy industry uses more of the total dairy production than any other division. Fifty-eight million quarts of fresh milk and cream are purchased each day by consumers through doorstep deliveries and in stores. There are more than 20,000 milk distributing companies or units of which more than one-half operate only one route. The average American drinks 349 lb. of milk a year, 13 lb. more than in 1924 *(2)*.

Changes in the Nature of the Dairy Industry

The past 50 years has also been a period of merging. The small independent dairies have felt the pressure of large volume competition, aggressive merchandising, and abundant capital. Many of the smaller plants have been purchased by large organizations and, although exact figures are not available, it is probable that more than 15% of all dairy products in the United States are sold by four major dairy organizations.

It also has been the period of organization of cooperatives. Small farmer cooperatives

were formed primarily to help solve the problems of marketing dairy products. Some of them failed; others succeeded. The successful ones became larger, merged, and became of major importance in the processing and distribution of milk. The most successful operations have probably been in the field of marketing fluid milk through the formation of producer milk marketing associations. The milk supplies of many major cities in the United States are controlled by cooperative milk producer associations. In some areas, they have limited their activities to marketing whereas others process and distribute milk products through their own facilities.

Dairying has become probably the most regulated of all industries. Standards have been set and laws passed that control the production, processing, and distribution of milk and dairy products. It has been the period when milk control boards, milk control commissions, and federal milk marketing ordinances were formed. It was the time of Lend-Lease, wage and hour laws, the Taft-Hartley law, greater organization of labor unions, government surpluses, multiple inspections, protective and prohibitory laws regulating inter- and intrastate shipment of milk and milk products, and numerous local and state laws and regulations controlling the price of milk.

The small producer-distributor who sold his milk retail has almost disappeared from the market. The passing of more stringent sanitary laws and regulations, the necessity for expensive processing equipment, higher wages, and greater feed costs have made it practically impossible for the small producer-distributor to compete with larger companies.

The past 50 years has been the period of development of motor transportation. The automobile, modern highways, and refrigerated trucks have had a great influence upon the dairy industry. Fifty years ago there were few wives employed in industry, incomes were low, and few people ate away from home. Buying in supermarkets, concern over diets, the demand for conveniences in the home are all developments of recent years.

In the marketing of dairy products there has been a swing away from retail delivery to supermarkets. This has necessitated single-service containers, more attractive cartons, greater choice of varieties, and point-of-sale merchandising. Some bad business practices have crept in, such as free ice cream, cabinets for dealers, excessive discounts, and the buying of stops. It has been the period of development in home freezers, vending machines, competitive food items, and more elaborate merchandising methods. Newspapers, color advertisements, television, and radio have all become of major importance in molding the buying habits of the public, and the use of these media by the industry has become universal.

The Golden Era has been the period of development of instant-soluble nonfat dry milk solids, chocolate drinks, cheese varieties, homogenized milk, vitamin D milk, multiple vitamin milk, sterilized milk, sterilized concentrated milk, frozen milk, and other new types of dairy products. Important development in the uses of milk for industrial products including plastics, glue, paint, clothing materials, and pharmaceuticals has been made through research.

Dairying has changed geographically since 1906. It has spread gradually towards the southeast and west. The southern states have been growing out of the Civil War reconstruction problems and utilizing more land for producing milk to feed an expanding population. The far west has become one of the leading dairy producing areas of the country. As the population migrated during the war years and moved from the east to the west and south, dairying became more important in those areas. Milk and its products are essential in the building of a healthy race of people. Consequently the dairy industry will long remain as an important part of the American way of living.

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Merchandising Dairy Products

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Since 1950, surplus agricultural commodities have constituted an important problem in the United States. When possible solutions to the problem are discussed, the dairy industry is frequently referred to as being a good example of what may be done by an industry toward solving its own problem. For nearly 20 years the industry has been organized to carry out through the support of producers a program of advertising promotion and merchandising. For more than 40 years the industry through contributions from all segments has conducted a national educational program to acquaint people of all ages with the nutritional value of dairy products. Much of this work has been through schools. The educational agency serves admirably as an intermediate between research and merchandising. It effectively backs up the merchandising program carried on through collective industry efforts as well as private advertising carried on by individual firms and corporations.

C. A. Iverson

Although these collective educational and merchandising efforts are younger than the American Dairy Science Association, the greatest assistance rendered merchandising efforts by members of the A.D.S.A. antedates the formation of the association. Members of the Association were engaged in the improvement of the quality and uniformity of dairy products before the Association was formally organized. It may be of interest to note, however, that standards of quality for dairy products were just emerging 50 years ago, for it was in 1906 also that the New York Mercantile Exchange established grades for butter.

Development of Merchandising Efforts

Through research and development, proper quality and composition standards were developed in cooperation with the industry. No other phase of the food industry has such a long record of support by the membership of its scientific society as does the dairy industry. The standards of identity for nearly all dairy products were established very early and are so exacting that deviations are now possible only with considerable difficulty. To some, these long established standards may appear to be unduly restrictive when food additives are considered. The early appearance of quality standards in dairy foods and their long-time usage provided a sound background of public acceptance for the establishment of merchandising programs. Probably no other food product has been accorded the confident acceptance of Grade A milk, for instance. The term has become synonymous with quality not only within the industry but also as a part of American slang, "strictly grade A." It is in this area of the over-all program of merchandising, comprising product research and development and the dissemination of information, that the members of the association have been pre-eminent.

Members of the American Dairy Science Association had an important part in the organization of the National Dairy Council nearly 40 years ago. The activities of this organization have been devoted to the education of the American public, particularly through its youth, regarding the nutritional value of dairy products. That its inception and activities have been sound is attested to by the enviable position enjoyed by the organization in its acceptance in our school system and its publications by the leaders of education. Its activities have helped immeasurably in the formation of a sound merchandising program for the dairy industry.

The formation of the American Dairy Association nearly 20 years ago was aided jointly by the work and encouragement of members of the American Dairy Science Association. Members of the A.D.S.A. not only encouraged and assisted in the formation of the national organization (ADA) but served as members of the boards of the national organization, as well as its counterparts in nearly every state in the union. In some states college staff members have served as managers or executive secretaries of the state affiliates of ADA. The research activities of ADA also have been served by A.D.S.A. members, both in the actual performance of the research as individuals and as advisors to the national program. These activities, together with the support of other events and activities such as June Dairy Month, give impetus to the merchandising programs for the entire dairy industry.

Aid in Marketing Dairy Products

Closely akin to the assistance which members of the American Dairy Science Asociation have rendered in merchandising dairy products are the efforts to assist the industry in marketing its products. In fact, it is difficult to draw a sharp line of demarcation between the two. In the earlier days of the

Association much help was given in advising producer groups in the establishment of local cooperative creameries and cheese factories. Later, marketing these and other dairy products became more complex, and assistance was given in the establishment of area marketing, examples being the Land O'Lakes organization in Minnesota, the Wisconsin state brand for cheese, the Dairymen's League of New York, the Iowa State Brand Creameries, and many others.

College courses. Many of our dairy industry college curricula include formal course work in merchandising and salesmanship, and most of them do have required courses in advertising and advertising psychology. In the field of extension activities no short-course program has been considered complete that did not contain discussions dealing directly with merchandising problems. Specialized conferences and short courses have been and are being held in dairy marketing. Not only has extension and resident teaching had broad marketing and merchandising implications, but the research work from its beginning, long before the advent of the American Dairy Science Association, concerned itself with standards of identity and the quality and uniformity of the products to be merchandised.

Merchandising has no recorded history whether it be for dairy products or any other commodity. In this respect it is not comparable to the research or teaching activities carried on by the members of the American Dairy Science Association. Each generation evidently must find out for itself the most desirable merchandising methods. The steps which have been taken by the dairy industry and the members of the American Dairy Science Association have, however, probably constituted a sound and logical approach, namely, the development of products of uniformly high quality; the education of the public in regard to their high nutritive value; and the advertising promotion and merchandising of these products by methods considered to be appropriate.

Growth in Number of Journals and Papers in the General Field of Dairy Science in the United States

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Prior to the establishment of the *Journal of Dairy Science* and for a considerable time after its inception, one of the most important media of publication was the experiment station bulletin. A comprehensive bibliography of the bulletins pertaining to the dairy industry from 1881 to 1947 was compiled by Albert R. Conley of the Ohio State University *(1)*. In it can be seen that as early as the 1880's a number of bulletins were published dealing with some phases of dairy research. In this category fall many experiment station bulletins bearing numbers from one to ten, indicating they were among the earliest ones published. In recent years, however, this form of publication has to some extent given way to scientific and trade journal articles, particularly in the field of dairy manufactures, chemistry, and bacteriology.

Joseph Tobias

Increase in number of publications. The growth of dairy publications is in no small measure related to the growth of the dairy industry. It is estimated that in 1850 there were 6.5 million cows in this country. By 1890 the number rose to 16.5 million and by 1910 to 22 million. The period from 1870 to 1910 was marked not only by a large increase in the number of dairy cattle but also by a considerable improvement in milk production per cow. The manufacture of butter in creameries was also on an upgrade. It is not surprising that during this period a number of dairy publications appeared for the first time.

Prior to 1870, dairy publications were limited in number. A list of agricultural periodicals which appeared between 1810 and 1910 was prepared by the United States Department of Agriculture *(2)*. The earliest recorded dairy publication was the *Dairyman's Record*, which was published in Little Falls, N. Y., in the years 1859 to 1860. It was succeeded by the *Dairy Farmer*, which appeared in the years 1860 to 1863. The only other periodicals listed as having appeared prior to 1880 were *Farm and Dairy*, established in 1874 at Ames, Iowa; *Practical Dairyman*, founded in Chatham, N. Y., in 1872; and the *American Dairyman and Butter, Cheese and Egg Reporter*, established in New York in 1872.

The period from 1880 to 1890. Many of the early publications were rather short-lived; some of them changed their name, some were consolidated with other periodicals, and others were discontinued. There is a certain historical interest, however, in listing all of them even though only about 30 of them survived past the year 1910. The following publications were established between 1880 and 1890:

American Creamery, Holly, Mich.
The American Dairyman, New York
The Dairy, New York
Dairy and Farm, Algona, Iowa
Dairy Farmer, Chariton, Iowa
Dairy and Farm Journal, West Liberty, Iowa
Dairy Messenger, Chicago
The Dairy World, Chicago
Farm and Dairy Herald, Hulmeville, Pa.
Farmer and Dairyman, Syracuse, N. Y.
Guernsey Breeder and Milk Journal, New York
Hoard's Dairyman, Ft. Atkinson, Wis.
The Jersey Bulletin, Indianapolis
Live Stock and Dairy Review, Chicago
Live Stock and Produce Review, Chicago
Market Review, Chicago
Michigan Dairyman, Grand Rapids, Mich.
The Milk Reporter, New York
New Dairy, New York
Northwest Farmer and Dairyman, Portland, Ore.
Practical Dairyman, Indianapolis
Practical Dairyman and American Stockman, Indianapolis
U. S. Dairyman

The period from 1890 to 1900. In the decade from 1890 to 1900, additional periodicals appeared:

American Cheesemaker, Grand Rapids, Mich.
American Creamery, Chicago
American Creamery and New York Butter Trade, New York
Butter Trade, New York
Chicago Dairy Produce, Chicago
Chicago Produce, Chicago
Creamery and Dairy, Clarksville and Waterloo, Iowa
The Creamery Gazette, Ames and Des Moines, Iowa
The Creamery Journal, Waterloo, Iowa
Creamery Messenger, Columbus, Neb.
Dairy Age, Beloit, Kan.
Dairy and Creamery, Chicago
Dairy Reporter, St. Paul
Elgin Dairy Report, Elgin, Ill.
The Jersey Bulletin and Dairy Farming, Indianapolis
Milk News, Chicago
The Milk Reporter and Dairy Record, New York
The National Dairyman, Kansas City, Mo.
The National Dairyman and Dairy Messenger, Kansas City, Mo.

Nebraska Dairyman and Up-to-Date Farmer, Lincoln, Neb.
News and Dairyman, Hartland, Wis.
New York Produce Review, New York
New York Produce Review and American Creamery, New York
Northeastern Iowa Dairy Journal, New Hampton, Iowa
Northwestern Creamery Journal, Minneapolis
Practical Dairyman and Agriculturist, Chatham, N. Y.
Southern Dairyman, Starkville, Miss.
Wallace's Farm and Dairy, Ames, Iowa
Wallace's Farmer and Dairyman, Ames, Iowa
The Western Creamery, San Francisco

The period from 1900 to 1910. In this period there was a rapid increase in the number of publications, as indicated by the following list:

Alamito Dairy Economist, Omaha
The American Goat Breeder, Chicago
Butter, Cheese and Egg Journal, Milwaukee
The Cheese and Dairy Journal, Whitewater, Wis.
The Cheese and Dairy Journal and Creamery Reporter, Whitewater, Wis.
Chicago Markets, Chicago
Colorado Dairyman, Denver
Cream Bulletin, Stockton, Calif.
The Dairy Bulletin, Bellows Falls, Vt.
The Dairy Bulletin, Macedonia, Ohio
Dairy Gazette, Lincoln, Neb.
Dairy and Live Stock, North Yakima, Wash.
Dairy and Produce Review, San Francisco
The Dairy Market Reporter, Whitewater, Wis.
The Dairy Record, St. Paul
Farm and Dairy Herald, Sheboygan and Plymouth, Wis.
The Guernsey Breeders' Journal, Peterboro, N. H.
Guernsey Breeders' Sales List and Bulletin
Heatwole's Dairy Paper, Northfield, Minn.
The Ice Cream Trade Journal, New York
Jersey Advocate and Dairyman, New York
Jersey Bulletin and Dairy World
Kimball's Dairy Farmer
The Live Stock and Dairy Journal, California
The Michigan Dairy Farmer, Detroit
The Milk and Cheese Journal, Milwaukee
The Milkman, Kansas City, Mo.
The Milk Producer, Chicago
Minnesota Dairyman, Northfield, Minn.
Missouri Dairyman, Jefferson City, Mo.
National Dairyman and Dairy Messenger, Chicago
Northwestern Dairyman, St. Paul
Northwestern Dairyman and Produce News, St. Paul
Pacific Dairy Review, San Francisco
Practical Dairyman, Rutherford, N. J.
Up-to-Date Farmer, Lincoln, Neb.
Western Farmer and Dairyman, Mankato, Minn.

The period from 1910 to 1920. The period after 1910 is of interest, for during this time plans were being made for the establishment of the *Journal of Dairy Science*. Unfortunately, an effort to locate a complete listing of dairy periodicals which appeared during the decade from 1910 to 1920 was not successful. However, a circular of the U. S. Department of Agriculture *(3)* lists periodicals received at the Department's library in 1922, in which the following dairy publications are included.

Angora and Milk Goat Journal, Portland, Ore.
Ayrshire Digest, Brandon, Vt.
Beatrice Meadow Gold Messenger, Chicago
Blue Valley Bulletin, Chicago
Butter, Cheese and Egg Journal, Milwaukee
California Dairyman, Los Angeles
Candy and Ice Cream, Chicago
Chicago Daily Market Letter
Chicago Dairy Produce
Creamery and Milk Plant Monthly, Chicago
Creamery Journal, Waterloo, Iowa
Dairy Farmer, Waterloo, Iowa
Dairy Record, St. Paul
Dairyman's League News, Waterville, N. Y.
De Laval Monthly, New York
Dutch Belted Cattle Association of America Bulletin and Live Stock Journal, Covert, Mich.
Goat World, Baldwin Park, Calif.
Guernsey Breeders' Journal, Peterboro, N. H.
Hoard's Dairyman, Ft. Atkinson, Wis.
Holstein Breeder and Dairyman, Harrisburg, Pa.
Holstein-Friesian Register, Brattleboro, Vt.
Holstein-Friesian World, Syracuse, N. Y.
Ice Cream Field, Atlanta
Ice Cream Review, Milwaukee
Ice Cream Trade Journal, New York
James' Barn Magazine, Ft. Atkinson, Wis.
Jersey Bulletin and Dairy World, Indianapolis
Michigan Milk Messenger, Fowlerville, Mich.
Milk Dealer, Milwaukee, Wis.
Milk Magazine, Waterloo, Iowa
Milk News, Chicago
Milk Reporter, Sussex, N. J.
Milking Shorthorn Journal, Independence, Iowa
National Poultry, Butter and Egg Journal, Chicago
New England Dairyman, Boston
New York Produce Review and American Creamery, New York
Northwest Dairyman and Farmer, Seattle
Oregon League Dairyman
Pacific Dairy Review, San Francisco
Resumé, New York
Southern Dairyman, Birmingham, Ala.
Urner-Barry Company, New York
Statistical Review of the New York Market
Western Milk Dealer and Dairyman, Seattle

The period from 1920 to 1936. In an effort to keep abreast of changes occurring in the dairy industry, publishers of certain periodicals have from time to time modified the names of their publications to reflect the thinking of the times. The following listing includes periodicals received in the Department of Agriculture library in 1936 that were not received in 1922 or that were appearing under a new name.

American Creamery and Poultry Produce Review, New York
American Creamery Operator and the Milk and Ice Cream Plant (North Dakota Creamery Operators Association and the South Dakota Dairy Association), St. Paul
Breeder and Dairyman, Harrisburg, Pa.
Brown Swiss Bulletin, Beloit, Wis.
Carnation Milk Farm News, Seattle

Certified Milk, New York
Dairy Produce, Chicago
Dairy World, Chicago
Denver Milk Market Review
Interstate Milk Producers Review, Philadelphia
Land O'Lakes News, Minneapolis
Michigan Milk Messenger, Detroit
Milk Inspector, Ventura, Calif.
Milk Plant Monthly
National Butter and Cheese Journal, Milwaukee
Northwest Daily Produce News, Seattle
Southern Dairy Products Journal, Atlanta
Vitamin D Milk, Standard Brands Incorporated, New York

The period from 1936 to 1953. The next list of serials received at the U. S. Department of Agriculture library appeared in 1950 *(5)*. A serial was defined as any publication issued regularly or irregularly for an indefinite period. It was considered current if it was not known to have ceased publication and if issues had been received since January, 1947. A supplement to the list appeared in 1953 *(6)*.

The list included the following serials that were not received in 1936 or were appearing under a new name.

American Butter and Cheese Review
American Dairy Cattle Club, Herd Builder
American Dairy Goat News
American Dairy Products Review
American Dairy Science Association, *Newsletter*
American Dairy Science Association—*Western Division Proceedings of Annual Meeting*
American Guernsey Cattle Club, Performance Register
American Milk Goat Record Association: *Advanced Register with Star Supplement Registration Table of the American Milk Goat Record Association*
American Milk Review
Avoset Dairyman
Ayrshire Times
Better Goatkeeping
Better Milking
Butter, Cheese and Milk Products Journal
California Milk News
Cheese Reporter
Cheese Trier
Cherry-Burrell Circle
Confectionery Ice Cream World
Co-operative Dairy Farmer
Cooperative Dairyman
Creamery Cooperator
Dairy and Poultry News
Dairy and Poultry Yearbook
Dairy Co-op Bulletin
Dairy Diary
Dairy Drummer
Dairy Farmer's Digest
Dairy Genetics News
Dairy Goat Journal
Dairy Guide
Dairy Herd Improver
Dairyland Digest
Dairyland News
Dairyman
Dairy Marketing Reports
Dairy News
Dairy Research Digest
Dairy Sire Directory and Line-breeding Guide
Eastern Milk Producer
Farm and Dairy
Holstein-Friesian Association of America: *Holstein-Friesian Herd Book Type and Production Yearbook*
Ice Cream Merchandizer
Jersey Bulletin
Jersey Review
Journal of Milk and Food Technology
Kraftsman
Milk and Food Sanitation
Milk Industry News
Milking for a Living
Milking Shorthorn Society: *Milking Shorthorn Year Book*
Milkman
Milk Market News
Milk Pail
Milky Way
Modern Dairyman
Northwest Dairyman
Pure-Pak News
Red Poll News
Sealtest Dairyman
Southern Dairy Goat News
Stock and Dairy Farmer
Surge News
United Dairy Goat Year Book
Urner-Barry Company: *Special Weekly Report—Butter, Eggs and Dressed Poultry*
Western Jersey Journal

This list is not complete in that it does not contain the publications of the various dairy products trade organizations such as the Milk Industry Foundation, American Butter Institute, American Dry Milk Institute, and others. Not included are many of the regional serials published by milk producers' associations, dairy cooperatives, dairy councils and state breed associations. Various annual reports and proceedings of annual conventions of such groups as the artificial breeding associations, International Association of Ice Cream Manufacturers, Milk Sanitarians Association, and others are omitted. State or federal government publications, Federal Milk Market Administrator announcements, State Dairy Products Association newsletters, State Milk Control Board publications, and various house organs are not included. It can also be assumed that certain serials were not received at the Department of Agriculture library; for example, the magazine entitled *Dairy Plant Production*, founded in 1922. On the other hand, a few periodicals whose existence was known to the author have been included even though they were not received at the Department of Agriculture library.

In an effort to compile a complete list of dairy serials a further complication arises from the fact that many papers dealing with dairy subjects are published in nondairy journals. This situation apparently has always existed and attests to the complexity of research performed in the general field of dairy

science. It should also be noted that many general farm magazines have been an important source of information to the dairy farmer.

Discussion and listings have been confined to publications originating in this country, thus excluding serials appearing in Canada and other English-speaking countries, some of which have a fairly good circulation in the United States. Of course, no effort was made to list foreign language publications, of which there is a considerable number.

We are living in what may be termed "a golden era" of communications. There has unquestionably been a tremendous growth in the number of papers, number of serials, and total circulation of printed work pertaining to the dairy industry. The result has been that the dairy farmers as well as the dairy plant operators are in position to be well informed of new developments. The dairy scientist has an opportunity to publish the results of his original research first in a scientific journal and then in a trade journal. Both are important, the scientific journal provides the minute details so important to other investigators, and the trade journal points out the immediate applicability. The *Journal of Dairy Science* provides an outlet for the original papers of research done in experiment stations and industrial laboratories. It has been, and will undoubtedly continue to be, an excellent publication medium. Its importance lies in the realization that it would be difficult for the industry to get along without it.

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(6) List of Serials Currently Received in the Library of the United States Department of Agriculture. USDA *Supplement* 1 as of March 1953. *Bibliographical Bulletin* 12, *Supplement* 1, July 1953.

Congratulations, A.D.S.A.

The National Dairy Council and its Affiliated Units appreciate this opportunity to congratulate the American Dairy Science Association on reaching its 50th year of progress. Your record of achievements in research and education have contributed immeasureably to the growth of the dairy industry. We are proud of being one of your associates in the industry and welcome occasions to work with you.

The National Dairy Council is in its 41st year of service to the dairy industry.

A non-profit, nutrition research, education and public relations organization, NDC was established by the dairy industry in 1915, with the assistance of leading dairy scientists, health authorities and nutritionists. It works through opinion-influencing leaders and groups on the national level, and locally through 71 affiliated Dairy Councils operating from 83 offices in 35 states.

NDC promotes the use of dairy foods in its health education program and a better public understanding of the dairy industry. It utilizes the most effective public relations tools available to disseminate nutrition information to national and local leaders who influence the food habits of consumers.

Millions of NDC's educational materials stressing the food value of milk, ice cream, butter and cheese are used by opinion-influencing leaders in their programs. Annually, more than 200 different educational pieces, in quantities well over 20,000,000, are distributed to leaders, who use the information in their own classrooms and offices. Included are sales promotion materials which the dairy industry uses to merchandise and promote its own products.

The program is financed nationally by dairy farmers, processors and distributors of dairy foods and manufacturers and jobbers of dairy equipment and supplies. Affiliated Dairy Council unit programs are financed locally by dairy farmers, milk processors and distributors and ice cream manufacturers.

Industrywide in action, nationwide in coverage and penetrating in sales effectiveness, the Dairy Council program serves as the market conditioner for sales of dairy foods.

NATIONAL DAIRY COUNCIL
111 NORTH CANAL STREET
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To the American Dairy Science Association

on its fiftieth anniversary

It seems more fitting to thank you for your many important accomplishments than to congratulate you for attaining the maturity of 50 years.

This we know: the American Dairy Science Association has been one of the key driving forces in bringing the most important single food in our diet to more and more people . . . a food that provides 74.3% of the calcium, 25.0% of the protein, 45.8% of the riboflavin, 17.3% of the Vitamin A, and important percentages of several other nutrients in our diet.

This we also know: that your creative and research activities have embraced the problems of production, sanitation, shipping, processing, packaging, and marketing. Under tutelage of your members:

- Milk production has increased more than 60%.
- Milk output per man-hour has about doubled in the past 50 years.
- Milk production per acre in forage crops has increased two-thirds.
- Compulsory pasteurization laws have become practically universal.
- Equipment used to transport, package, and process milk and milk products has been brought to a high state of perfection.
- Homogenization and Vitamin D fortification are now commonplace.
- Every-other-day milk delivery has helped keep the price of milk low to the consumer.
- Milking machines, barn cleaners, better management methods, and farm mechanization have emancipated the dairyman and kept milk and milk products a low-cost staple for the consumer.

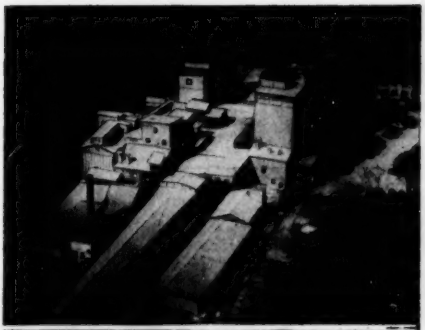
We thank you . . . not for the memories . . . but for what you have done to make our people healthier, happier, and more productive.

Lilly

AGRICULTURAL AND INDUSTRIAL PRODUCTS DIVISION
ELI LILLY AND COMPANY • INDIANAPOLIS 6, INDIANA

WIRTHMORE Serves The Dairy Industry

EXPERIENCE in supplying feeds which help the user reap the greatest possible benefit has come to Wirthmore through its many years of making fine quality feeds. Born in a little grist mill in Lancaster, Massachusetts, back when prepared feeds were the simplest of mixtures, Wirthmore now serves the dairy, livestock, and poultry industries from Michigan to the Atlantic with its seven modern feed mills.



RESEARCH in better feeding, better materials, and better blending is an ever-present objective with us. The feeds and the feeding directions which more specifically meet the needs of the animals, the application of American mass production methods, and an efficient distribution system contribute to the profit of the user.

SERVICE has always been more than a slogan for Wirthmore. It has been an ideal to live by for the men who produce the feeds, those who deliver them, and for the large staff of trained men so well known on farms as Wirthmore Service Men.

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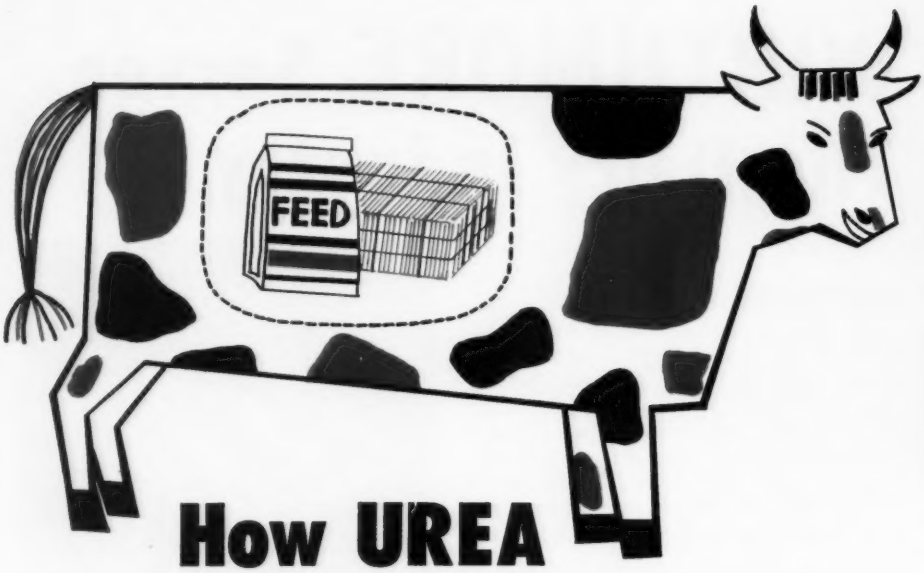

How UREA gets into a cow's rumen

Many high-quality dairy feeds today contain Urea. Most farmers as well as scientists know that this practical source of protein is produced in large factories by combining ammonia and carbon dioxide.

But few farmers know that they have always fed their cattle small amounts of Urea in farm feedstuffs. Oats, alfalfa, wheat mill feeds, and even oilmeals, contain Urea as well as other non-protein forms of nitrogen. In ground oats, Urea makes up as much as 4½% of the total nitrogen content.

Cattle themselves also put some Urea into their digestive systems in their own saliva. This Urea is taken from the blood and recycled to the rumen.

PROCADIAN*
UREA
FEED MIXTURE
The QUICK Source of PROTEIN in Mixed Feeds

Other non-protein forms of nitrogen are even more common than Urea in farm feeds. Amino acids, amides and other non-protein components of the "crude" protein may supply over 20% of the nitrogen in young, growing feed plants. Non-protein nitrogen and Urea are not new in the feeding of ruminants. For reprints of recent literature on this interesting topic, write now.

NITROGEN DIVISION
Allied Chemical & Dye Corporation
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NITROGEN DIVISION ALLIED CHEMICAL

"New Dairy Research Unit. (1) Calf and Maternity Barn, (2) Four Loose Housing Units, (3) Hay Storage and Feeding, (4) Twin Barn, (5) Feeding Barn, (6) Holding Shed, (7) Milking Parlor."

What's going on at **MoorMan's** *?*

In this space we can only sketch our activities. But if you'll stop in to see us at Quincy you can see for yourself how important dairy science is to us.

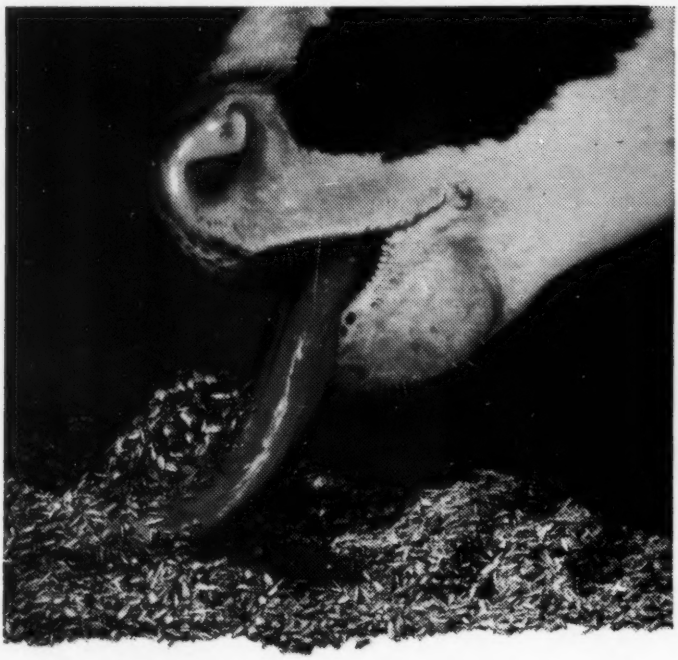
In our Research Laboratories we'll show you the genesis of a great variety of nutritional research problems. Then we'll show you how—on our 515-acre Research Farm—we test and prove the practicability or impracticability "of our ideas."

At the Research Farm we're just completing what we believe is one of the most modern Dairy Research Units in America today. In each of our 4 loose-housing units we will have 25 cows for group experiments. And, in our twin barn we have 16 pairs of *identical* twin cows which will give us accurate comparisons of feeding and management practices.

Then we have a feeding barn where, on the way to our modern milking parlor, individual animals get their carefully weighed concentrate rations. Our milking parlor, which handles 6 cows in line, is equipped with a glass pipe line system leading to refrigerated bulk storage. In addition we have a calf and maternity barn for approximately 100 calves and cows.

Though dairy research may be your *primary* interest we're certain that you'll find many other projects of interest on the Farm, in our Laboratories and in our modern feed factory, where we manufacture concentrate feeds (Mintrates*) and mineral mixtures for livestock and poultry. Do plan to stop and see us. There's nothing we enjoy more than welcoming friends. *Moorman Mfg. Co., Quincy, Illinois —a business dedicated to helping farmers make better and more profitable use of the feeds they raise themselves.*

*Trademark Reg. U. S. Pat. Off.



Hazel had the answer on the tip of her tongue

HAZEL'S an important cow at Larro Research Farm. She helped tell Larro nutritionists how feeds taste by taking her pick in free-choice tests.

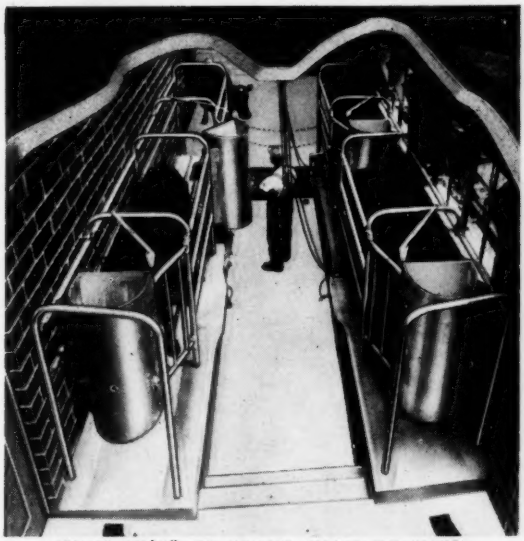
Recently, Hazel showed without a doubt which feed she preferred. She chose Larro's new tasty-texture SureMilk formula . . . and ate 58 lbs. after a full feeding of roughage.

The reason: Larro SureMilk is light, but not loaded with dusty fines. The fine particles are pelleted and mixed well with coarser ingredients. Just enough molasses is added to sweeten the feed without covering up natural flavors.

Tasty-texture SureMilk has now been proven by dairy herds from coast to coast. Dairymen report that their cows like tasty-texture SureMilk . . . clean it up fast with no waste . . . stay healthy and produce their best, even on poor pastures or roughage. It's made by General Mills and backed by over 40 years of quality feed-making experience.

GENERAL MILLS
Minneapolis 1, Minnesota

SM-1-5-R



ONLY 10'6" OF SPACE, WALL TO WALL

COWS ENTER FROM HOLDING AREA

Entrance and exit doors operate easily from pit. Cows bring milk to you—move easily through Clay Walk-Thru Stalls—save you work—time.

MEASURED FEEDING

Once cows are in Clay Walk-Thru Stalls feeding is easy. Turn crank and feed measures automatically from hopper into pan. Makes overhead feed bins practical—easy.

MILK FASTER IN FAR LESS SPACE

Milk 30 cows per hour with Clay Walk-Thru Stalls. Takes only 10'6" of space, wall to wall. You're only two steps away from any chore. Cuts building and modernization costs too.

Walk-Thru Stalls make milking easy

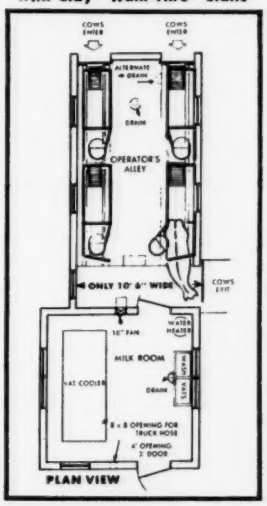
Milk faster—save steps, work and time—get cleaner milk with Clay Walk-Thru Stalls. In a low-cost, four stall parlor, one man easily handles 30 cows per hour. GRADE "A" MILK plant requirements are easily met at low cost with Clay Walk-Thru Stalls . . . efficiency is improved and cost of help is cut to absolute minimum.

NO STOOPING, bending, carrying. Everything is handy in a small area. Work is cut in half.

ALL GALVANIZED, for low maintenance cost. Strength enough for many years of service.

LOW BUILDING COST—because stalls act as alley. Require less space—can cut building cost 30%.

Typical Grade "A" Milk Plant with Clay "Walk-Thru" Stalls



PLAN VIEW

SKETCH YOUR IDEAS of planned improvements and mail to Clay. You will receive free standard floor plans and money saving ideas. This special service costs nothing . . . can save many sleepless nights. Also, free books for dairymen. Write today. Mail coupon.

Modern Equipment . . . for easier farming!

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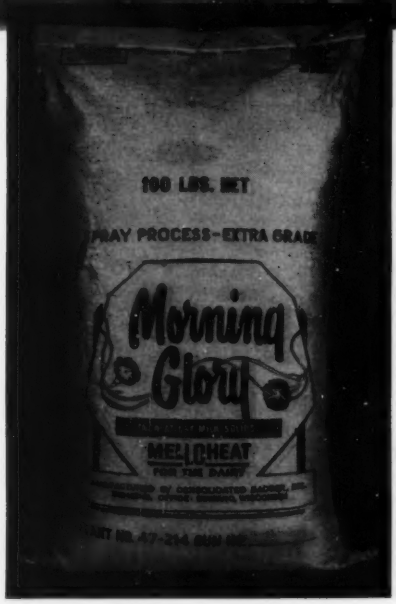


quality-control at the high concentrators

Fresh, rich milk from inspected farms . . . processed in clean, modern plants located throughout Wisconsin . . . inspected, tested again and again, at every step in production — guarantees the uniformly high quality of Morning Glory nonfat dry milk solids. In the development and application of this product, Consolidated Badger has shared a productive partnership with the dairy scientists of America.

Morning Glory
NONFAT DRY MILK SOLIDS

CONSOLIDATED BADGER, INC., SHAWANO, WISCONSIN

To: THE AMERICAN DAIRY SCIENCE ASSOCIATION . . .

ITS OFFICERS AND MEMBERS . . .

We wish to extend congratulations on the completion of 50 years of progress in research, teaching, and extension in the field of DAIRY SCIENCE.

The future of the food industry depends largely upon progress in research. Our companies are the result of progress in research. We are dedicated, therefore, to perpetuate this progress in whatever way possible.

The G. Frederick Smith Chemical Co., Inc. specializes in the development and manufacture of rare chemicals for research purposes. We supply research laboratories in all the principal countries of the world. Many of our products are employed in control operations in the food processing industry.

The Aerated Processes, Inc., originators of the patented process of whipping cream with nitrous oxide, operate plants in 50 cities of the United States under the trade name "Instantwhip."

Write either company for brochures relating to scientific products control in your field of specialization.

G. Frederick Smith, President
G. Frederick Smith Chemical Co. Inc.
Aerated Processes, Inc.
Columbus, Ohio

MAINTAIN TOP QUALITY

in

- *cottage cheese*
- *cultured buttermilk*
- *ice cream*
- *chocolate drink*
- *fortified fresh skim*

with

WESTERVILLE'S

The Mojonnier (low temperature) process of dry milk production avoids denaturization of protein, thus assuring superior quality in your dairy products. Westerville's Lo-Temp gives greater yield . . . finer flavor . . . perfect uniformity . . . and better mixing results than non-fat dry milk solids produced in less modern ways.

Made from Grade A and Extra Grade Powders
Available in 50-lb. and 100-lb. bags.

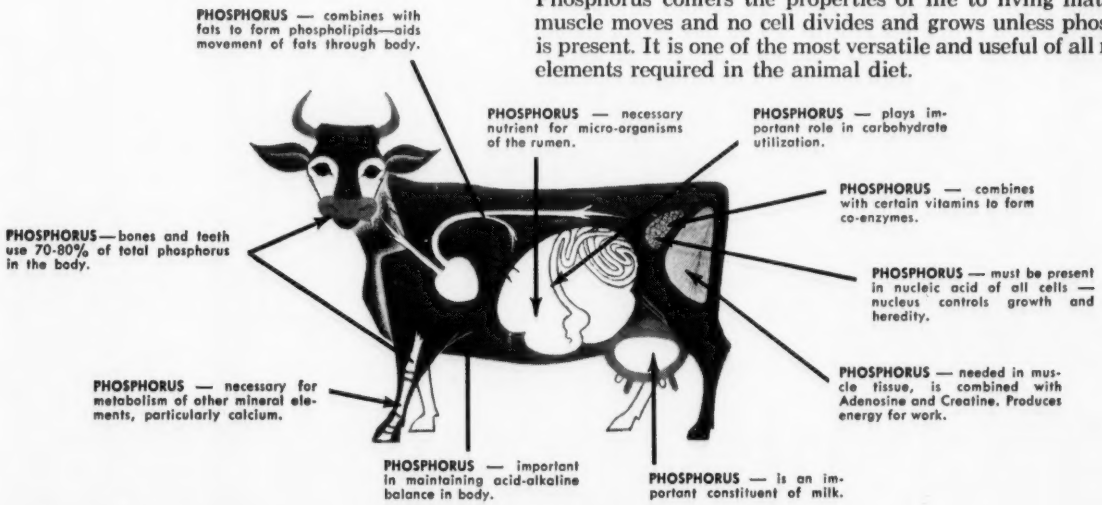
Inquiries welcomed from dairies located east of the Mississippi

WESTERVILLE CREAMERY

WESTERVILLE, OHIO COVINGTON, OHIO

THE *DYNAMIC* ROLE OF PHOSPHORUS IN METABOLISM

Phosphorus confers the properties of life to living matter. No muscle moves and no cell divides and grows unless phosphorus is present. It is one of the most versatile and useful of all mineral elements required in the animal diet.


PHOSPHORUS — combines with fats to form phospholipids—aids movement of fats through body.
PHOSPHORUS — necessary nutrient for micro-organisms of the rumen.
PHOSPHORUS — plays important role in carbohydrate utilization.
PHOSPHORUS — combines with certain vitamins to form co-enzymes.
PHOSPHORUS — must be present in nucleic acid of all cells — nucleus controls growth and heredity.
PHOSPHORUS — needed in muscle tissue, is combined with Adenosine and Creatine. Produces energy for work.
PHOSPHORUS — is an important constituent of milk.
PHOSPHORUS — important in maintaining acid-alkaline balance in body.
PHOSPHORUS — necessary for metabolism of other mineral elements, particularly calcium.
PHOSPHORUS — bones and teeth use 70-80% of total phosphorus in the body.

Today's bred-up livestock produce more . . . need more nutritional power to deliver their best. Yet, farm feeds in many areas are often more deficient today. In this way, phosphorus has become of vital importance. That's why modern feeds need a harder-working phosphorus to assure optimum performance. Through the magic of radioactive isotope research, we now know more about the dynamic roles of phosphorus in metabolism. These vital roles are diagrammatically illustrated above.

MINERALS *International* CHEMICALS

Dynafos — 18½% P
dicalcium phosphate
Multifos — 18% P
tricalcium phosphate
Defluorofos — 13%P
tricalcium phosphate

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U.S.I. FEED NEWS

★ A SERIES FOR SCIENTISTS AND EXECUTIVES OF THE FEED MANUFACTURING INDUSTRY ★

Drought Conditions May Cause Deficiency of Vitamin A in Roughage for Cattle

One of the indirect losses caused by drought conditions is a decreased vitamin A content in hay and other roughage. When drought or other factors cause roughages to be below par, rations should be properly supplemented with vitamin A to help prevent unthriftiness and reproductive troubles, as well as staggering and paralysis in advanced cases of deficiency.

Special adaptations have been worked out by state experiment stations on their "standard" formulas to provide increased vitamin A fortification. The Purdue and Iowa cattle supplements are examples.

U.S.I. Permadry, a sealed-in vitamin A product, contains 10,000 U.S.P. units of vitamin A per gram. Permadry has excellent stability in storage and unusual biological availability. For further information contact the U.S.I. office near you.

NEW CONCEPT IN RUMINANT NUTRITION FINDS PRACTICAL USE

A liquid feed supplement based on a new concept in ruminant nutrition is reported to produce increased milk production in dairy animals and more economical weight gains in beef cattle. The patented supplement contains a mixture of molasses, urea, phosphoric acid and an active hydrogen donor, along with all the essential minerals known to be required by cattle.

The new feed supplement is the result of research on the nutritional requirements of rumen micro-organisms, with particular attention to hydrogen donor systems in microbial metabolism. The supplement speeds up rumen fermentation processes, enabling cattle and sheep to eat and assimilate more feed in a shorter time.

The liquid supplement may be fed free-choice to cattle at all stages of their development and does not cause the toxic effects experienced with earlier molasses-urea mixtures. The manufacturer is now marketing the new supplement nationwide.

DAIRY CALVES SHOW GAIN ON ANTIBIOTIC MIXTURE

A mixture of four antibiotics, including penicillin and bacitracin, has been found to increase significantly the weight of dairy calves. The mixture gave better results than other antibiotics fed singly.

U.S.I. Feed News A Regular Feature

Each month U.S.I. publishes a full page FEED NEWS in leading publications reaching nutritional and feed formulation specialists. References on any FEED NEWS article may be obtained by writing EDITOR, U.S.I. FEED NEWS, 99 Park Ave., New York 16, N. Y.

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- VACATONE* 80 (molasses distillers dried solubles)
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- U.S.I. NIACIN
- U.S.I. CALCIUM PANTOTHENATE Products
- U.S.I. DL-METHIONINE (feed grade)
- U.S.I. VITAMIN A & D Products (stabilized)

*Reg. U.S. Pat. Off.

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99 Park Avenue, New York 16, N. Y.

CORONET DEFLUORINATED PHOSPHATE

QUALITY

Repeated nutritional evidence establishes CDP as the best phosphorus supplement.

SERVICE

You can be assured of continual supply and uniform quality in highly available phosphorus-low fluorine CDP.

VALUE

CDP is the lowest-cost, quality phosphorus product available. All of the phosphorus in CDP is biologically useable.

TWO GRADES to Meet Your Requirements

		17% P Grade	14.5% P Grade
Phosphorus,	Total	17.0% min.	14.5% min.
Calcium,	Total	34.0% min.	34.0% min.
Fluorine,	Total	0.17% max.	0.145% max.

Let us figure the cost of CDP Delivered to Your Plant

Coronet Phosphate Company

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Congratulations

ON 50 YEARS OF PROGRESS!

We at Armour and Company are proud to be associated with the work and progress of the American Dairy Science Association.

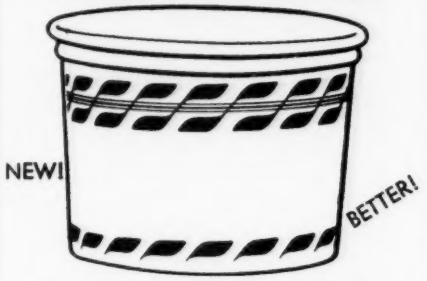
Our pride is clearly reflected in the quality of the fine dairy products that bear the Armour Star Label.

Just a few of the many famous Armour Star dairy products

ARMOUR AND COMPANY

General Offices: Chicago 9, Illinois

DIXIE HEAVY DUTY FOOD CONTAINER



Dixie Heavy Duty Food Container *seals moisture in!* Keeps moist dairy foods fresher far longer! Dixie offers new closures, too. From transparent plastic closures to economy disc lids! Write for free samples!

Variety of Special Dairy Designs Includes:

Basket Weave Farm Tableware

Not all Food Containers are DIXIE CUPS —just the best ones!

DIXIE CUP COMPANY, EASTON, PA.

*RIPPLE IS RIGHT!

FOR ICE CREAM SALES

Feature monthly specials of 13 wonderful flavors—simply ripple Balch's Ready-to-Use Ripple Sauces into your own vanilla ice cream. NOTE: All Fruit and Butterscotch Ripple sauces are PURE!—contain no artificial flavor.

Send for details & free Advertising Helps.

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Greetings and Congratulations
to the
American Dairy Science
Association
on the
50th Anniversary
of its founding

DAIRYMEN'S LEAGUE
COOPERATIVE
ASSOCIATION, INC.

Syracuse General Laboratory
Syracuse, New York

MABC SALUTES

AMERICAN DAIRY SCIENCE ASSN.

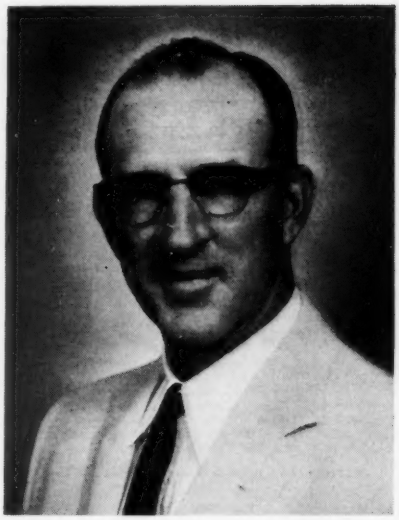
ON ITS 50th ANNIVERSARY!

For the outstanding service rendered to the dairy industry of America in the past and with the wish that the next 50 years may be just as productive, MABC congratulates the American Dairy Science Association.

The aim of all artificial breeding associations is for continuous improvement of dairy cattle. We know they join with us in extending our congratulations.

MICHIGAN ARTIFICIAL BREEDERS COOPERATIVE, INC.
BOX 511 EAST LANSING, MICH.

Evolution in milk containers is shown from top left to lower right: Ceramic and crockery, to tin-plated steel, to glass, to disposable cartons.



"We believe that fresh milk and Pure-Pak go together. Both our customers and our employees appreciate the advantages of Pure-Pak cartons," says Mr. Freeman Hales, president of Miami Home Milk Producers Association, Miami, Florida.

This month is Dairy Month. A time to salute the dynamic dairy industry, guardian of milk—one of the nation's vital resources.

THE NEW STORY OF MILK

begins in the "parlor"

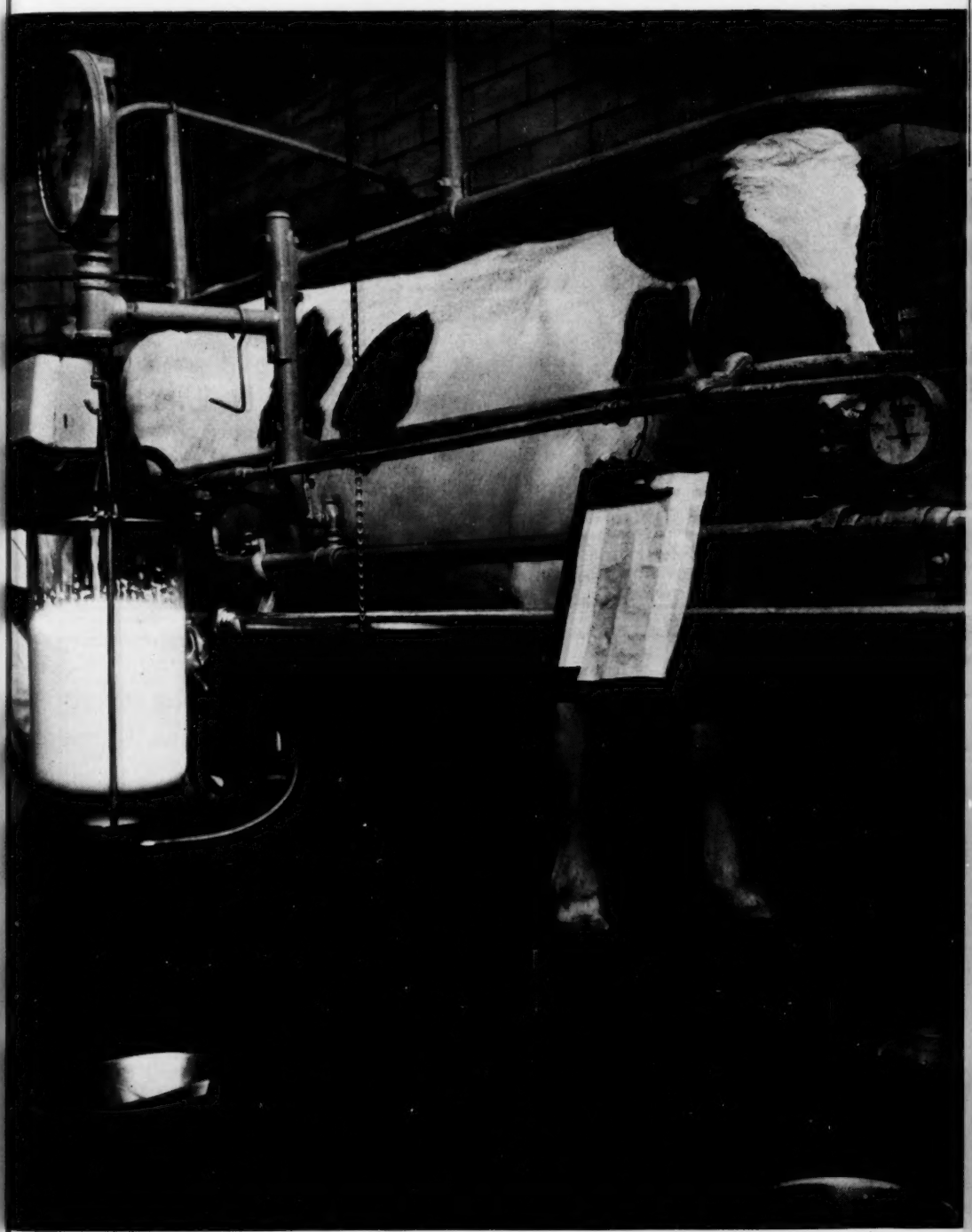
As she enters the bright, clean "milking parlor," bossie is brushed, washed, and the automatic milker is attached. Milk flows from the milking machine to holding tank, to tank truck, to dairy.

Rigid cleanliness is maintained in the dairy through automatic processing and packaging in disposable Pure-Pak cartons. Pure-Pak cartons assure that your milk comes to you with all its natural freshness and good taste sealed in . . . protected as never before!

Modern milk handling and new packaging convenience are the New Story of Milk.

Pure-Pak disposable containers are safe, light, easy to handle. They save precious space in the refrigerator. Everybody likes them! More than ⅓ of all bottled milk is sold in Pure-Pak today!

Pure-Pak milk cartons are a product of Ex-Cell-O Corporation, Detroit 32, Michigan



THIS ADVERTISEMENT ALSO APPEARS IN JUNE LADIES' HOME JOURNAL

CONGRATULATIONS A. D. S. A.!

The independent dairy products manufacturers, members of Quality Chekd, pay homage to the American Dairy Science Association on this 50th anniversary in recognition of the many significant and invaluable contributions made to our dairy industry by the members of A.D.S.A. through the years.

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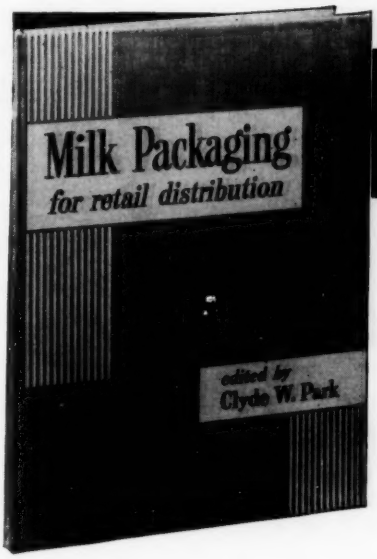

JUST OFF PRESS!

A Significant Contribution to the Dairy Industry

***Edited by* Dr. Clyde W. Park**

CONTRIBUTORS:

Ernst & Ernst, nationally recognized cost accountants

Charles Roberts Associates, marketing research

COMMENTATORS:

Dr. Ira Gould, Chairman of Department of Dairy Technology, Ohio State University

Dr. Elmer F. Baumer, Professor of Agricultural Economics, Ohio State University

On the fiftieth anniversary of the American Dairy Science Association, Suabedissen-Wittner Dairy of South Bend, Indiana, The Champion Paper & Fibre Company and Gardner Board & Carton Company are honored to make available to the dairy industry a significant piece of research. Now for the first time, a scientifically thorough investigation on the packaging of fluid milk for retail delivery provides a fact book that you can apply to your own dairy operation.

Here's a complete picture of the experience of the Suabedissen-Wittner Dairy of South Bend, Indiana, in packaging and distributing milk. For dairy operators, the detailed, *side-by-side comparison between an all-glass and an all-paper operation* explains many of the factors that enter into the costs of processing and distributing fluid milk in retail.

In observing the experiment and insuring that all factors were weighed in their proper relationship, Dr. Ira Gould, Chairman of the Ohio State University's Department of Dairy Technology and Dr. Elmer F. Baumer, Professor of Agricultural Economics at Ohio State University, have helped to clear up widespread misunderstanding in the dairy industry on milk packaging and distribution methods.

The consumer attitude study, conducted by the research firm of Charles Roberts Associates, sheds new light on the importance of consumer opinion in the use of different packaging materials.

Long a baffling problem on how to identify and allocate cost factors for each of the two packaging methods, the nationally recognized cost accounting firm of Ernst & Ernst has provided an accurate picture of cost factors, some of which can be projected to your own retail milk operation.

Are you interested in this information?

- Packaging and storage costs of fluid milk
- Delivery costs for retail operation
- Time distribution of plant men to activities
- Proper allocation of certain plant costs to products
- Route drivers and expense—wholesale and retail
- Time-study breakdown—filling, capping, change-over, start-up, etc.
- Consumer attitudes—glass versus paper containers

A. H. Pugh Printing Company, Dept. CE
400 Pike Street, Cincinnati 2, Ohio

Please send postpaid a copy of *Milk Packaging for Retail Distribution.*

Enclosed is check for $5.00 ☐ Please send C.O.D. ☐

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Partners in Progress

PIONEERS in American Dairy Science know that their numbers include the researchers and technicians of the Joe Lowe Corporation.

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Call any Joe Lowe office for complete information on the services available to you.

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IODINE DAIRY SANITIZERS

Iodine has long been recognized as a most efficient antiseptic and germicide. For many years iodine has been tested extensively and has been found effective against a wide range of organisms.

Now the known bactericidal values of iodine are available to the dairy industry. Iodine preparations formulated especially for the sanitization of dairy utensils and equipment offer greater effectiveness in low concentrations.

Iodine dairy sanitizers are supplied by important producers. The products are easy to use, easy to test. The well-known iodine color is an indication of solution strength.

Write us for further information on iodine's values in the field of dairy sanitation.

CHILEAN IODINE EDUCATIONAL BUREAU, INC.

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FOR THOSE 50 PRODUCTIVE YEARS OF ACCOMPLISHMENT —

Our Congratulations

Fifty years ago Wyandotte Cleaner and Cleanser, a modified soda product, was successfully replacing the use of soap powders for the cleaning of dairy equipment. We well remember that soap powders, due to their poor rinsing characteristics, frequently imparted soapy flavors to milk.

Fifty years ago the founding of the American Dairy Science Association began, for the Dairy Industry, a coordination of college and industrial research investigations.

The results of these combined, concentrated efforts are clearly apparent in the progress which has been made in production, in manufacturing processes, in the improvement of the quality of dairy products. Apparent, too, is public appreciation for the nutritional values which milk contributes to the health of all people.

To keep pace with this progress, Wyandotte developed a highly productive and efficient Industrial Research Center. *Now*, nucleonic methods are used in determining the merits of products used for the cleaning and sanitizing of dairy equipment.

Wyandotte research work on the chemistry of cleaning has developed products suitable for the satisfactory cleaning and sanitizing of the complex equipment now used in the handling and processing of milk.

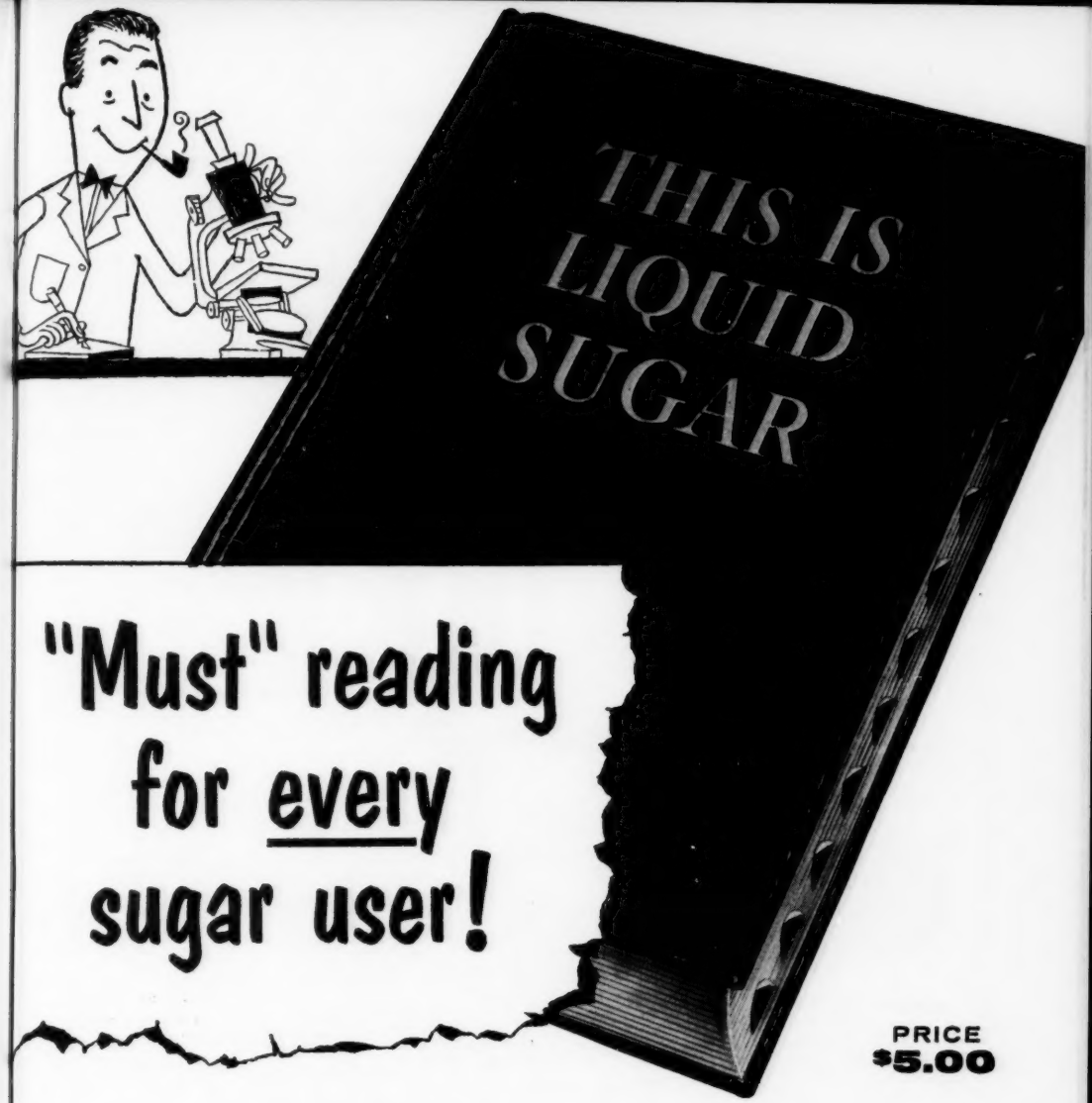
Wyandotte Kelvar*—a mild alkaline cleaner containing sequestering agents combined with synthetic detergents.
Wyandotte Cle-Chlor—a chlorinated product for C.I.P. cleaning.
Wyandotte Servac*—a liquid acid cleaner.
Wyandotte Antibac*—a fast-acting organic chlorine germicide.

We congratulate the American Dairy Science Association for its many and great contributions to the Dairy Industry during these past fifty years.

*Reg. U. S. Pat. Off.

Wyandotte CHEMICALS

J. B. Ford Division
Wyandotte Chemicals Corporation
Wyandotte, Michigan — Los Nietos, California



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PRICE $5.00

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"Here are some of the important subjects this valuable reference work covers: history, production, and distribution of liquid sugar; liquid sugar systems; techniques of using liquid sugar in major food industries and dozens of pages of charts, graphs and tables covering every aspect of liquid sugar use."

You can arrange with your Flo-Sweet Engineer for your copy of "This Is Liquid Sugar" — or you can obtain the book direct from Refined Syrups & Sugars, Yonkers, N. Y. Price $5.00.

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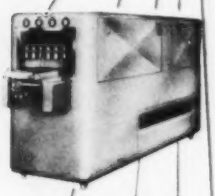
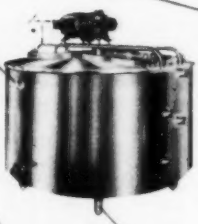
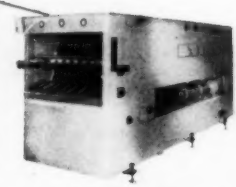


ICE CREAM MOLD WASHER
10 or 20 Molds per minute.

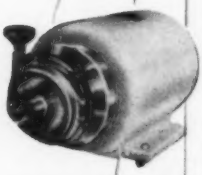


PROCESSORS
50 to 1000 gal.—Vacuum and Open Top. Choice of Pressure Wall, Steam Vapor, Flooded or Spray Heating.



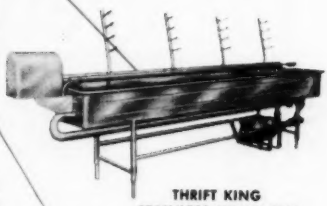
SOAKER BOTTLE WASHERS
Half-Pint Bottles to Half-Gallon and Gallon Jugs.

SANITARY PIPE & PARTS WASHING EQUIPMENT
A size for every dairy, from the smallest to the largest.



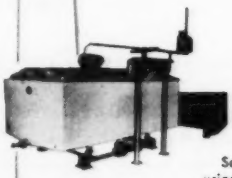
COMPENSATING IMPELLER PUMPS
Automatically adjusts to varying head pressures. From ¼ to 7½ HP.

STORAGE TANKS
For Milk, Ice Cream Mix, By-Products. Unrefrigerated or Refrigerated.



THRIFT KING STAINLESS PIPE TANKS
Equipped with Pipe Washing Machine and Recirculating Unit.

ROLL-A-TABLES



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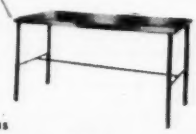
10 or 20 Cases per minute.



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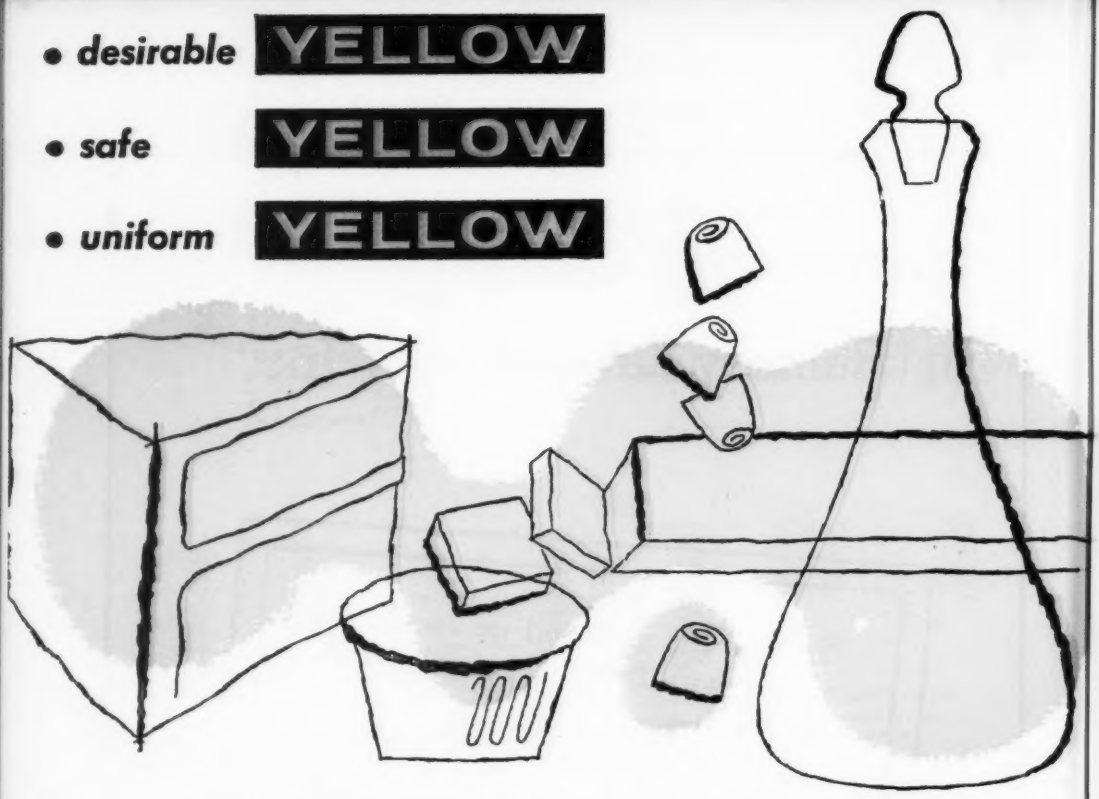

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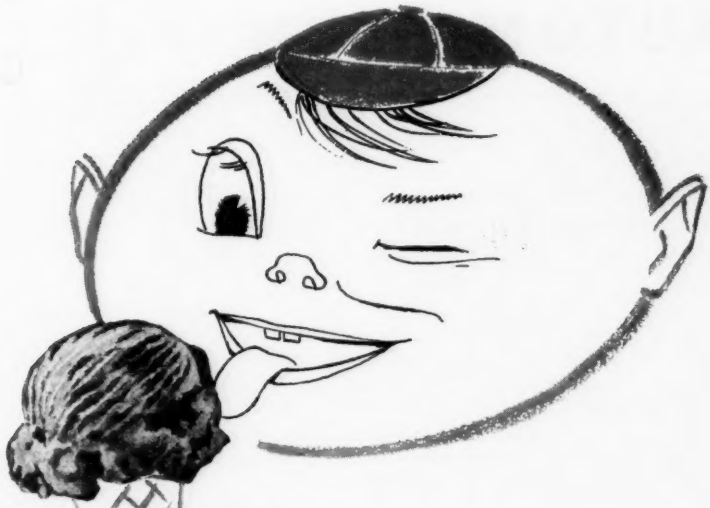

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Alert merchandisers, whose business it is to study consumer needs and desires, know from experience that whether served in sodas, sundaes or cones, *freshly-dipped* ice cream tastes better, looks better and builds certain and profitable repeat sales. Encourage your fountain and food-serving customers to feature *freshly-dipped* ice cream, so easily dispensed from National's "Locktop" Paper Cans for Bulk Ice Cream.

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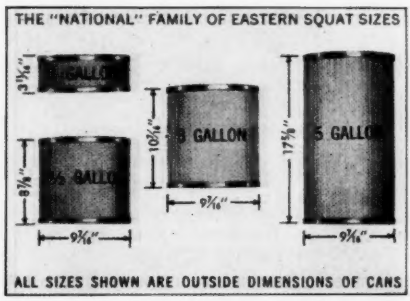

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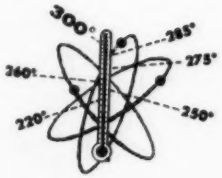
AUTOMATION  IN

destroys bacteria **in three seconds** **without changing flavor**

Here's a totally different concept in pasteurization that makes present standards in bacteria-kill obsolete. Destroys bacteria at extreme high heat without altering the natural flavor of milk and other dairy products.

Already accepted by public health authorities . . . already proved by production installations in ice cream plants and related food processors.

THE FIRST SUPER-HEAT CONTINUOUS-PRODUCTION PASTEURIZER

Complete inlet-to-outlet cycle takes three seconds, is fully automatic. One product flavor can follow another without stoppage. Capacity 16,000 pounds per hour. Entire unit is adaptable for in-place cleaning. Compared with conventional equipment, savings in labor costs for operating, cleaning and maintenance soon pays for cost of equipment. You are cordially invited to write for complete information.

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LOWEST BACTERIAL COUNT

The new Roswell-Hi-Heet Process is guaranteed to destroy bacteria at these extreme high temperatures to the count of practical sterility. This offers the opportunity for greater profit in terms of longer shelf life, better flavor, less spoilage and less frequent delivery schedules.

ALMOST MAINTENANCE FREE

No costly gaskets to replace. Front and rear manifolds require only simple, paper-composition gaskets, costing a few cents a day. No product loss from leakage or spillage.

SAVES LABOR COSTS

Fully automatic. Continues operation as set on controls. One man can tend numerous machines. Equally practical for large or small batch processing. With small batches, one after the other may be processed without shut-down, since the small amount of product in the unit (1½ quarts in each tube) prevents excess mixing of batches.

ELIMINATES OR LIMITS NEED FOR STABILIZERS

Ice cream processed in the Roswell at 250° F. for three seconds gives superior body, texture and flavor with little or no stabilizer needed. Provides tremendous savings compared with conventional batch method.

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The Roswell Hi-Heet Pasteurizer overall is only 2 feet wide, 7 feet long and 6 feet high . . . yet processes up to 16,000 pounds per hour. Here's real productivity in a few feet of plant space!

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Plants that have existing plate type equipment can adapt it to the Roswell process as a regenerative section, if so desired.
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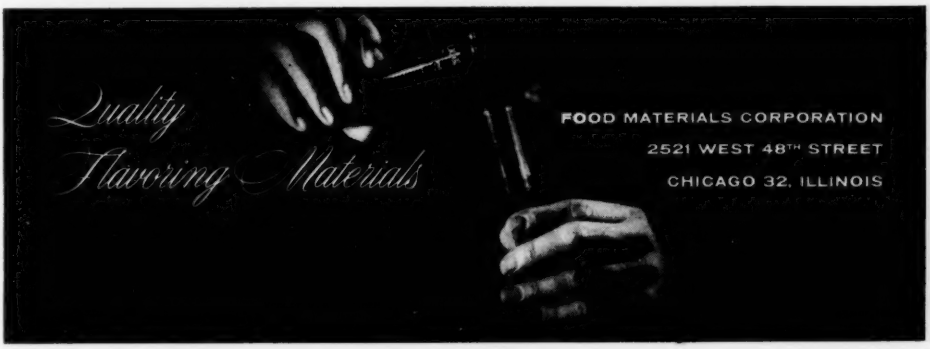

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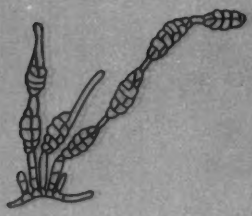

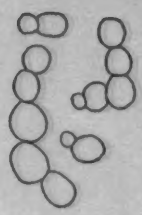

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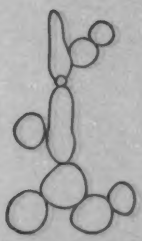

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